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Stanford Research Inst.

Prepared For
Environmental Protection Agency

April 1976

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EPA-600/9-76-022

Final Report *April 1976*

RESEARCH TO ANTICIPATE ENVIRONMENTAL IMPACTS OF CHANGING RESOURCE USAGE

Symposium Proceedings

Prepared for:

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

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SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

1. Report No. EPA-600/9-76-022

2.

3. Accession No. W

4. Title
RESEARCH TO ANTICIPATE ENVIRONMENTAL IMPACTS OF CHANGING RESOURCE USAGE

5. Report Date April 1976

6.

7. Author(s)
Kendall D. Moll, editor

8. Performing Organization Report No. 3570-17

9. Organization
Stanford Research Institute
333 Ravenswood Avenue
Menlo Park, California 94025

10. Project No.

11. Contract/Grant No.
68-01-2940 #17

12. Sponsoring Organization Environmental Protection Agency

13. Type of Report and Period Covered Final
April 1975 - April 1976

15. Supplementary Notes

16. Abstract

This compilation of papers by 14 eminent authorities from government, academia, industry, and other institutions deals with research and policy problems facing EPA from recent and prospective changes in the availability of such natural resources as energy, minerals, agricultural land, and clean air and water. Among its major themes are the complex nature of interactions among resources, environments, and social values; and the need for research into the patterns of these interactions. Other themes call for increased research emphasis on patterns of resource flow and usage, on economic and social incentives for controlling the environment, on emergent potentially critical ecological problems, on several specific applied research and technology development programs, and on environmental monitoring and assessment techniques. The papers were delivered at a symposium held at Stanford Research Institute, August 27 and 28, 1975.

17a. Descriptors

Abundance
Assessments
Consumption
Depletion
Ecology
Environmental engineering
Environmental surveys
Mineral economics
Natural resources
Resources
Social change
Social organization
Systems analysis
Research
Research management

17b. Identifiers

17c. COWRR Field & Group

PRICES SUBJECT TO CHANGE

18. Availability

19. Security Class. (Report)

20. Security Class. (Page)

21. No. of Pages 254

22. Price $9.00

Send To:
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WRSIC 102 REV JUNE 1971

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Menlo Park, California 94025 · U.S.A.

EPA-600/9-76-022
April 1976

Final Report

RESEARCH TO ANTICIPATE ENVIRONMENTAL IMPACTS OF CHANGING RESOURCE USAGE

Symposium Proceedings
STANFORD RESEARCH INSTITUTE
333 RAVENSWOOD AVENUE
MENLO PARK, CA. 94025

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WASHINGTON, D.C. 20460

PREFACE

Inspiration for holding the Symposium which is reported in this Proceedings arose from concern within EPA about the decreasing availability of many natural resources, the impacts of changes in resource availability on environmental issues, and consequent needs for research by EPA. Because the subject has many facets and is not uniquely structured within EPA's or any other federal agency's existing research program, the sponsors wanted to obtain a wide spectrum of ideas from experts in government, industry, academia, research, and public interest groups. The resulting symposium was held August 27 and 28, 1975, at Stanford Research Institute in Menlo Park, California.

A program representing a variety of disciplines was arranged with papers presented by leading authorities on the subject of natural resources and the environment, from various professional disciplines. The formal program consisted of a keynote and three background papers, five viewpoint papers, and five reviewer responses. All of these papers, together with Introduction and Conclusions sections, are included in this Proceedings.

Meeting invitations were also extended to a select audience with varied backgrounds, who were expected to participate in general discussions and specialized workshops. A list of the participants and attendees is attached at the back of this Proceedings.

Special appreciation is due Drs. James Hibbs and Harold Kibbee of EPA, who guided the conceptualization and organization of the symposium. Helpful comments on the Proceedings draft were obtained from Mr. E. S. Allen of Cyprus Mines Corporation, Mr. Michael Rothenberg of the San Francisco Bay Area Air Pollution Control District, and Dr. Richard A. Schmidt of the Electric Power Research Institute.

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INTRODUCTION AND SUMMARY

Willis W. Harman, Director
Center for the Study of Social Policy, SRI

Congress has stated a national policy to "restore and enhance the quality" of the environment as it affects all aspects of human well-being. This policy is developing in a context of uncertain but surely soaring demands on resources of all sorts. The conflicts and dilemmas of this situation, and the needs for research to reduce uncertainties and resolve problems, form the focus of attention of the papers and discussion that made up this symposium.

The 13 contributors were all requested to address the same two questions--namely:

- What factors may change patterns of resource usage in the future, and how?
- What research needs and priorities do these changes suggest, to improve the nation's ability to anticipate future environmental consequences?

The contributors were deliberately chosen to approach these questions from widely diverse points of view. The intent--and in this respect the symposium was especially successful--was to avoid unproductive adversary confrontation and to engage in mutual exploration of the issues, taking full advantage of the enhancement contributed to a diversity of perceptions. A number of participants remarked on the need for mutual respect in resolving the wide range of viewpoints.

A Central Theme

In spite of the wide spread of viewpoints, one theme turned out to be omnipresent. It was emphasized in different ways by various speakers and in comments by audience participants, but never forgotten and never contradicted. That was the affirmation that a fragmented view of resource usage, economic development, and environmental problems can no longer be considered adequate, and a total-system interdisciplinary approach is essential. Often heard as a pious wish, this imperative was expressed here as a basis for prompt action.

In the form of a crucial question, this central concern surfaced again and again throughout the symposium. Is extrapolation of present resource consumption trends, even with all environmental protection measures now contemplated, compatible with human well-being in fundamental respects--psychospiritual as well as material needs, wholeness and mental health as well as physical health? Or will it be necessary to move very far and very fast in the direction of closed, ecologically sound industrial processes and resource-frugal lifestyles, with revisions in the economic structure as necessary to accommodate?

The impetus for this question comes from the environmental implications of exponentially increasing world demand for physical resources coupled with rapidly growing U.S. dependence on external sources (partly a consequence of environmental controls). But it comes equally from what one speaker called "the explosive growth in our actual and potential capacities to intervene in the larger environmental processes." "The scale of our human systems begins to approach magnitudes which can affect larger areas and relationships in the biosphere."

A major implication of the question is that important as environmentally protective technology development may be, it is not enough. The crisis we face--and most agreed it is a genuine crisis--is an institutional crisis. The most perplexing problems center around needs for institutional revisions.

Discussion of the central theme tended to focus on three major concerns for the future: (a) forces opposing resource frugality, (b) forces opposing environmental protection measures, and (c) difficulties of planning for technological change. Together these concerns generate a majority of the high-priority research needs brought out in the symposium.

Forces Opposing Resource Frugality

Obviously the environmental impact of resource usage could be lessened if the use were reduced. Yet the demands of the economy seem to actively oppose environmentally and ecologically sound developments in a number of ways. Both from the standpoint of historical data and from a logical basis (since goods and services tend to use resources), there is a strong correlation between economic product and resource demand. Any move toward resource frugality that cuts into economic product will be opposed by forces within the economy, since its internal logic as well as the pressures of continuing world population growth requires continuing increases in production.

Economic forces and what has passed as good business practice urge consumers to replace their present durable goods with new ones--better or just different. Politically motivated taxation, subsidy, or price control schemes may force inefficient production patterns. Both are in opposition to the environmentally sound concept of designing for durability and ease of repair. Economic reasoning dictates using the cheapest source for materials; this may conflict with the principle of designing and planning for the total life cycle of materials. Economically efficient management would opt for the cheapest acceptable means of waste disposal; ecologically good management involves waste processing to produce usable by-products. Efficient management uses the most cost-effective production processes; ecological whole-system management aims at closed industrial processes that minimize waste disposal demands on the environment.

Efficient resource production uses the cheapest methods legally permissible under existing environmental protection legislation; ecologically sound resource utilization uses the methods that do least violence to the local environment and to the total life-support system of the planet. Conventional business wisdom argues that business should be as free as possible from governmental intervention, and antitrust interpretations in the courts tend to inhibit collaboration among corporations for any purpose. Yet whole-system considerations indicate that closed industrial processes can come about only if business organizations and governmental agencies can interact very closely together.

The dominance of economic incentives over other whole-system considerations is clearly central to many of the most serious environmental problems. To repeat--"the crises are not in energy, in technology, in the environment; they are all institutional crises." That is they are the results of specific values, attitudes, and institutional arrangements for using these elements of the system.

Forces Opposing Environmental Protection Measures

Some characteristics of the future seem ineluctable; however, much choice may be left for other characteristics. General trends of recent decades will continue into the future in a number of environmentally relevant respects:

(1) The present culture of developed nations and the expectations of developing nations require ever-increasing resource usage. (For example, world production of mineral resources is doubling approximately every 7-8 years.) This tends to imply ever-increasing environmental impacts associated both with resource supply and with resource consumption.

(2) Resources in general will be more expensive both because of their scarcity and because they will require higher levels of technology input and greater capital investment. This tends to imply greater environmental impacts associated with resource supply.

(3) Resources of many sorts (fossil fuels, minerals, natural fresh water, arable land) will be increasingly harder to locate and extract or exploit, and will involve more environmental dislocation for their exploitation.

(4) There will be resource scarcities of various sorts, and increasing U.S. dependence on external sources; hence, there will be tremendous pressures to develop indigenous U.S. and foreign resources, including those that have been uneconomical to develop at past prices and availabilities. These pressures will tend to overwhelm environmental concerns.

(5) There will also be tremendous pressures on U.S. agriculture to produce food for the world market, both to meet external food crises and to balance huge payments for foreign oil. These pressures too will tend to override concern for the environment.

(6) The world will become increasingly unstable over the world food issue. There will be soaring demands for capital for large energy projects and urban reconstruction, in a debt economy, hindering the financing of environmental protection equipment. All these will tend to increase the severity of environmental problems.

On the other hand, sensitivity to environmental issues seems likely to increase. Disappointments over inability to meet previously set goals will be one factor in this direction. There will be more frequent and more sudden impacts on planetary life-support systems because of increasing magnitude of technological interventions and the great complexity of these ecological systems that precludes "complete modeling" and accurate prediction. Also, the threat of irreversible global impacts may become more apparent.

Thus we seem headed for increasing confrontation between the industrial system and those segments of human welfare that depend on biotic resources. To repeat--this creates an institutional crisis.

Difficulties in Planning

Besides the conflict between intrinsic economic incentives and ecological motivations, and the anticipated extreme pressures because of other societal problems, environmental restoration and enhancement faces another kind of difficulty--the limitations on our ability to do long range planning. Various reasons for this were pointed out in the discussions--the compartmentalization of knowledge, the constrained time attention span in both business and government, limited understanding of how large and complex social systems really work, the irrationality in dealing with certain issues of the usual economic discounting of the future, and the overall tendency of short-term problems to drive out long range planning.

If we have difficulties accomplishing long range planning, it is doubly true that we do not know how to do long-range whole-system planning. And it is increasingly evident that we must learn. Several of the speakers went into more detail on what this implies.

Some Whole-System Aspects

A convenient representation of resource-environment relationships in an industrialized society appears in Figure 1. The planet provides fundamental resources in what seemed until very recent years essentially unlimited quantity. Chief among these are surface area, air, water, topsoil, solar energy, biota, and subsurface concentrations. The so-called primary industries (agriculture, forestry, fishing, extractive industry, and in earlier years hunting and trapping) deal with the conversion of these into derived resources (basic foodstuffs, natural fibers, minerals, fossil fuels, saw logs). Some of this is used directly by consumers. However, as the degree of industrialization increases, a larger and larger fraction of the derived resources is used by secondary and tertiary

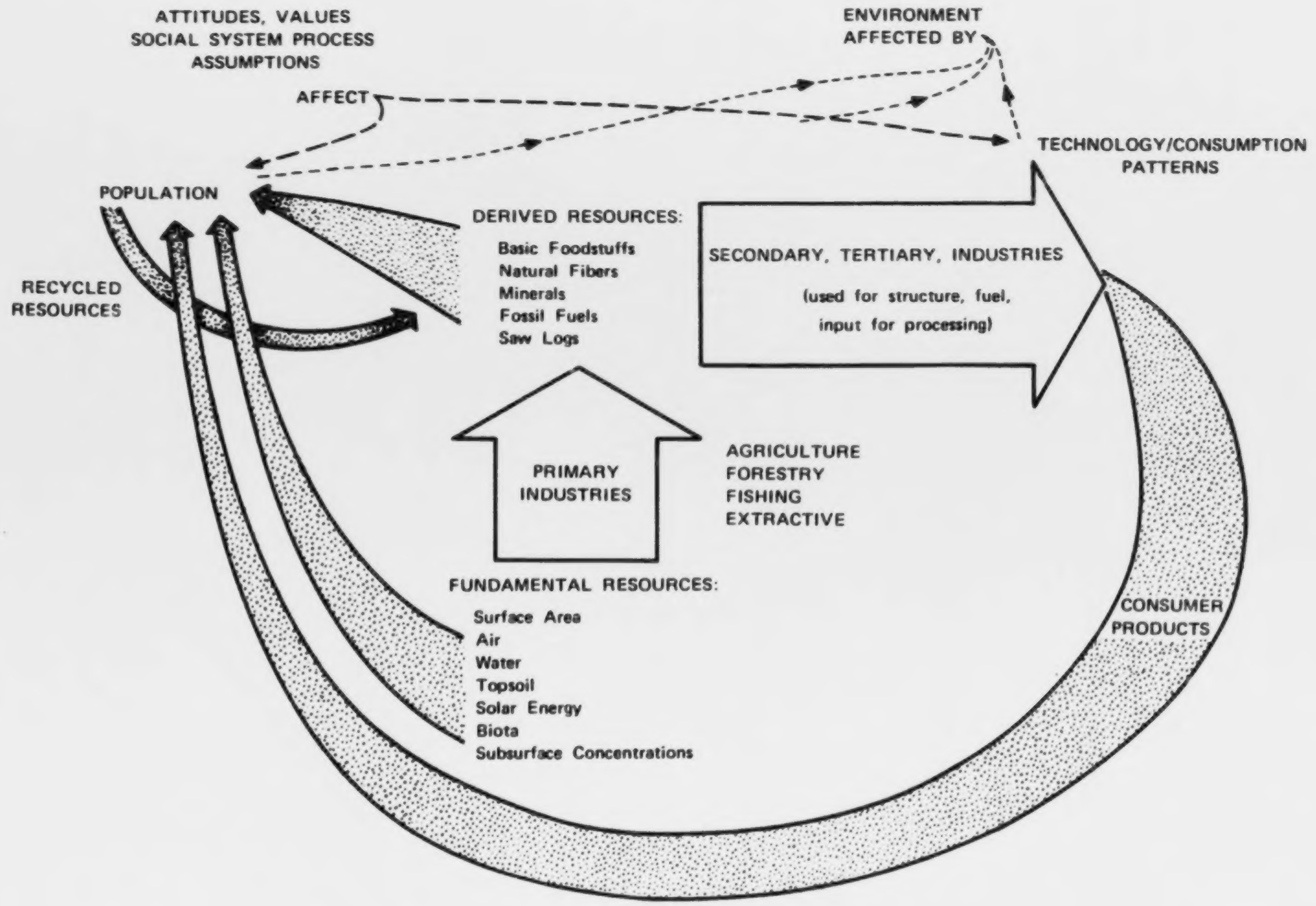

FIGURE 1 RESOURCE – ENVIRONMENT RELATIONSHIPS

industries (for structure, as fuel or energy, and as input for processing) to produce goods and services to be used by consumers.

Environmental impact comes from the use patterns of resources and products of various types, from the production of derived resources by primary industries, and from the technology associated with production of consumer products by secondary and tertiary industries. People's attitudes, values, and embedded assumptions affect the overall system characteristics. This, in simplified form, is the system involved in whole-system change.

Figure 2 is an attempt to represent in matrix form what was earlier termed the central theme of the symposium. There are a number of major problem areas in society that are recognized as being to a greater or lesser extent interrelated--problems of the physical and social environment, problems relating to food supply and distribution, to energy, to matters of income and power distribution, to resource depletion, and so on. Often these are dealt with as though they were separately resolvable by technological and legal approaches (e.g., SO_2 pollution abatement through stack gas scrubbers; water pollution removal through effluent regulations). The problems may be alternatively perceived as amenable to management and incentives approaches (e.g., land use policies to preserve physical environment; effluent taxes to reduce air and water pollution).

But as the pressures on the environment have grown and the interrelationships among the various problem areas have become more apparent, the problems become resolvable only by whole-system change. The limiting pattern of resource use becomes the closed system within which resources are transformed (but not "used up" and discarded), the by-products of one process becoming the input stock for another, the whole designed so as to produce minimal disturbance to the earth's basic chemical and

PROBLEMS PERCEIVED AS RESOLVABLE:	INTERRELATED PROBLEM AREAS					
	PHYSICAL ENVIRONMENT	SOCIAL ENVIRONMENT	FOOD	ENERGY	DISTRIBUTION EQUITY	RESOURCE DEPLETION
By Technological and Legal Approaches	e.g. Stack Gas Scrubbers, Air Pollution Regulations	e.g. Desegregation Regulations, Street Lighting for Safe Streets	e.g. Green Revolution	e.g. Breeder Reactors, Higher Efficiency Engines	e.g. Direct Aid to Less Developed Countries	e.g. Law to Prohibit Throwaway Containers
By Management and Incentives Approaches	e.g. Effluent Taxes, Land Use Policies	e.g. Social Programs to Reduce Crime	e.g. Farm Subsidies	e.g. Energy Tax	e.g. Industrialization Assistance to Less Developed Countries	e.g. Economic Incentives to Reclaim Materials
Only By Whole-System Change	e.g. Modifying Fundamental Characteristics of the Industrial Production System; Redistributing Population and Industry to Reduce Transportation Needs					

FIGURE 2 CONTRASTING PROBLEM PERCEPTIONS

biotic patterns. Examples are integrated industrial processes and urban sewage systems that return organic waste to the land.

In this systemic view of societal problems a number of intermediate objectives could be set to reduce environmental impact through:

- Selection among alternative materials, processes, and products on the basis of low environmental impact as well as economic cost
- Changing extraction processes
- Changing transportation needs
- Changing resource processing
- Changing materials usage in fabricating and packaging
- Improving durability and repairability of products
- Increasing resource reclamability.

To attain these intermediate objectives would require in most cases a combination of a strong environmental ethic and altered incentive structures, since desirable changes from an environmental standpoint would not necessarily be those that would increase return on investment or market share.

Longer range objectives--extending over more than a decade--are even more difficult to achieve through planned intervention. Examples would be adjusting economic and other incentives to promote redistribution of population and industry, and to foster land use planning to reduce transportation needs. Another example might involve de-industrializing food production to reduce agricultural energy demand, transportation, packaging, and processing energy. Research needs for long range programs are great, since little is known about what specific system changes would be desirable, and how they might be brought about. Such needs can best be met by research programs that are individually low-cost and high-risk (of significant results) in contrast to the high-cost low-risk research programs that are normally supported.

Bases for Selecting High-Priority Research

From the various symposium discussions, as well as the arguments above, emerged a number of proposed high priority research areas. The most important of these are:

- Research on emergent critical problems, especially those involving potentially global and irreversible impacts
- Research to improve ability to anticipate critical problems
- Research to resolve critical uncertainties of a substantive nature
- Research to resolve critical uncertainties of an interpretive nature (e.g., whether the society is entering a period of relatively fundamental transformations)
- Monitoring areas of critical uncertainty.

Guide to Individual Papers

The prepared papers that constitute the central framework of the symposium include (1) the keynote and three background papers, (2) five papers addressing the two theme questions from diverse points of view, and (3) five responses to those papers from five additional points of view.

An Administrator's Viewpoint. William Ruckelshaus, first Administrator of the EPA provided some remarks from his vantage point. He reminded the symposium participants that the pioneers of EPA took considerable satisfaction in having created the Agency to attack in a coordinated way the interrelated problems of air and water pollution, pesticides, solid-waste, and land use. Even so, they later found that environmental problems cannot be separated from the whole social fabric. The problem is less one of advancing the technology than of understanding what costs should be accepted for what benefits. The new realities of changing resource usage require new patterns of coordination--EPA, ERDA, and FEA working together on energy conservation, the recession forcing attention to the economic impacts of environmental regulations, EPA and Agriculture working together on low environmental impact agricultural methods, and so on. Equally, they require new abilities to continually look into the future, to anticipate and accommodate to future threats to environmental goals.

Background Papers. The first background paper, by John McHale, stresses the institutional nature of the resource crises, mentioned earlier. The very concept of a resource grows out of the institutions of the society and their perceived needs. Industrialized society is creating an explosive growth in resource needs, environmental impacts, and capacities to intervene in the planet's life-support processes. If industrial growth seems to lead toward "neo-Malthusian" hypotheses of inevitable catastrophe, it is because of an implicit assumption that the basic institutional characteristics will remain unchanged. With a guided transformation of the industrial world's institutions, it is possible to conceive of accommodating more balanced growth and high technological development with lowered resource demand and lowered environmental impact. But this view emphasizes changes in perceptual and conceptual "worldviews" which accompany, and often precede, significant social, economic, and political change. Resource usage patterns and environmental impacts are inherent in a particular worldview, and will change fundamentally only as that worldview changes. We need "to recognize that the environment is not only modified by physical actions, but by our ideas, beliefs, and value systems. . .and the ways in which they operate to influence policies and environmental decisions even more than do material techniques."

Ted Gordon's background paper has a similar tone. He notes the huge increasing demand for resources with the ineluctable conclusion that the environment will be severely stressed in producing and disposing of the demanded materials. The conclusion is "irrefutable," that exponential growth of world population and resource-depleting production must ultimately end--the questions are when and how. "Not very soon" is Gordon's answer to when. The question of how leads him to the conclusion that the industrialized and industrializing worlds face an unprecedented cultural and institutional crisis. In spite of promising technologies, he doubts that the necessary changes can occur fast enough to resolve the contradiction between increasing resource demands and environmental consequences. Gordon predicts "chaos" and suggests additional technological measures to buy time.

The third background paper by Maurice Eastin focuses on the need for a more system-oriented view of resource utilization. The environmental problem can never be satisfactorily resolved through fragmented regulation of air, water, and earth impacts. Yet dealing with all these plus the planet's living and life-support systems in an integrated fashion is out of reach. Faced with the inability to deal with the total life-and-environment system, yet with the fact that "we cannot live with the economics of the end-of-the-pipe environmental point of view," we need to look toward an intermediate target--more efficient subsystem processes from the standpoints of resources, economics, and energy. The basic processes of industrialized society (e.g., agriculture and food, paper and pulp, construction materials) need to be approached with a systems orientation, with an eye to converting waste products to by-products and new products. This is an approach toward which EPA is evolving, moving from negative restrictive control to positive environmental synthesis.

First Viewpoint. Lynton Caldwell presented the first of the five viewpoints. He emphasized the need for an improved framework of knowledge about the general and basic causes of our environmental predicament. Lacking an adequate conceptual framework, we lack the basis for guiding research to bring our general environmental situation under control;

attacking specific problems of environmental protection may invite others equally unwelcome.

One of the key points highlighted by Caldwell is the political, conceptual, and psychological difficulty of dealing with the resource-environment problem in the consumption phase rather than concentrating efforts almost solely on the supply phase--that is, of seeking an improved system rather than "making the present system work better." With regard to research priorities, Caldwell argues for "a structure or hierarchy of environmental knowledge that would be larger than the operational agenda of any agency, but which could provide orientation and perspective for the research missions of organizations such as the EPA." For an assortment of political and cultural reasons this most-needed research is very difficult for any government agency or even foundation to support. We will probably have instead a much less systemic, more risk-averse, problem focused, and ultimately less effective and more costly research program.

Stanley Cain argues only mildly with Caldwell in commenting on his paper. He further emphasizes the need, and the difficulty, of a broader scope for inquiry than can with propriety be mounted by a government agency with legally restricted cognizance. As Cain says, "the holistic science of ecology is well and working." We are coming to realize "the intricate interconnections of life and environment." Yet because of compartmentalization of knowledge and of institutional responsibility, it will be difficult to acquire the knowledge, authority, and understanding we require to resolve our environmental problems. Although "it is profitless to do research only on existing resource-use patterns," this is predominantly what we will do. We need to see our problems whole. Yet the temptation instead is to find someone to blame. The lesson we have yet to learn is, "When the causes are shared by everyone, when the system is at fault, the victims are the culprits."

Second Viewpoint. Robert North's paper explores in more detail the implications of an interdisciplinary systemic view. Arguing that environmental consequences come essentially from three variables--population, resources, and technology--he elaborates the need for research to model all of these together, taking into account the complex pattern of social, economic, and political changes on their interrelationships. A large portion of North's discussion goes to making the point that our accustomed ways of dealing with problems are ill adapted to problems that are systemic in character. As he puts it, "a social system tends to draw our attention to the very points at which an attempt to intervene will fail." We tend to look close to the symptoms of trouble for an apparent cause; however, that cause is not the basic cause, and thus the proposed remedy turns out to be ineffective or to produce "unintended consequences" or counterintuitive results." Through lack of understanding of how the whole system operates, and through lack of an accepted goal structure, micro-decisions are made that sum to bad macro-decisions for the overall society. This will be exacerbated as we move into a period of intense competition for critical resources. Thus the highest priority should be assigned research on system simulation, whole-system forecasting, and evaluation of alternative assumptions and alternative courses of action for the future.

Earl Heady, in commenting on North's paper, expresses himself as more optimistic that the difficulties of interdisciplinary research on total life-environment-society systems can indeed be surmounted. He notes successes in interdisciplinary university research efforts, in large-scale modeling, in evaluating tradeoffs and comparing the consequences of alternative policies to substantiate his point. He urges research on incentive systems (e.g., taxes, subsidies) for political implementation of values (e.g., clear streams, natural beauty) not expressible in the marketplace (i.e., externalities), and to ameliorate the problem of excessive discounting of the future. Secondly, he sees the need for expanded research efforts on modeling complex social systems. Finally, he urges altering EPA's research approach to a more positive and long-term emphasis on developing technologies and resource that avoid deleterious environmental consequences.

Third Viewpoint. At first reading, the paper by Ralph d'Arge may seem to strike a different note. He defines an emerging class of environmental problems: ones where extremely long-term or irreversible impacts might occur, where multinational and even global impacts are anticipated, and where the set of outcomes is at least partially unknown and highly uncertain. He points out that present guides to decision-making do not adequately take into account possible long-term and potentially irreversible effects. He notes the limitations of modeling when assessing the range of plausible outcomes; "man will not (ever) understand in detail the interweaving patterns and forces within his own ecosystem" because he can never observe all the interdependencies. And we have no effective way of handling problems of the "global commons" (e.g., the oceans the stratosphere, nuclear wastes). d'Arge urges high research priority for this class of problems, and concentration of research funds on the most impending of these. This emphasis on control strategies for a limited class of environmental problems seems superficially distinct from the emphasis on whole-system approaches advocated in so many of the other papers. However, the difference turns out to be more apparent than real, because when these "most urgent" problems are examined the solutions appear to lie less in technological advance than in system change.

William Cooper agrees that d'Arge identifies a set of problems that will be of increasing concern "as synthetic compounds are developed and produced in a frantic effort to escape the ultimate constraints of material limitations and/or the thermodynamic implications of dependence on closed energetic systems." The difficulty with controlling these problems using economic incentives, standards, regulations, and penalties, is that the control system must be designed to perform almost flawlessly. The alternative approach is system redesign to achieve satisfactory performance and resilience assuming that there will be individual and institutional mistakes which no system of control will be able to prevent. Again the prime need expressed is for a research program on overall system control and design supported by experimental approaches to incremental change.

Fourth Viewpoint. The paper by George Woodwell centers around the confrontation between the industrial system with its emphasis on short-term profits and those segments of human welfare that depend on biotic resources, a confrontation that must become steadily more acute with instances more common. The alternative to the present situation is clear. In a world with soaring population and soaring demands on resources, the basic pattern in use of the environment must become the closed system. The basic principle is not pollution within limits, to be corrected. It is, rather an approach toward no pollution by designing cities, industries, and agriculture to be as nearly as possible self-contained, recirculating water, nutrients, metals, and wastes in ways that do not make excessive demands on the "assimilative capacity" of the environment. The central principle is the preservation of the earth's basic chemical and biotic patterns, as written into the policy statement of the Water Pollution Control Act Amendments of 1972. The research needed to guide the transition to closed systems would include, as examples (a) a continuing analysis of the world's carbon budget to discern when dangerous imbalances occur, (b) a program to discover the details of biotic impoverishment and how to recognize the earliest stages of it, and (c) a vigorous program on the recirculation of water and nutrients in sewage.

Sid Galler's comments on the Woodwell paper are mainly by way of emphasis. Agreeing with Woodwell's basic principle of "no pollution; not pollution within limits" and with the urgency of attention to impacts on the global carbon budget, Galler disagrees sharply on one point. He contradicts Woodwell's suggestion that the EPA should be given responsibility for basic research to preserve "the earth's basic chemical and biotic patterns." Galler's argument is that this large and important task requires resources and capabilities going far beyond those likely to be, or appropriate, for a primarily regulatory agency, and that the knowledge required for this task derives from a wide variety of basic and applied research investigations that are appropriately carried out in a diversity of existing agencies.

Fifth Viewpoint. John Zierold's paper concentrates on the energy and world food crises, and the pressures these will bring on the environment. Among the topics are environmental impacts of urban sprawl, resource recovery from low-concentration sources, resource processing and transportation, preservation of prime agricultural lands, and preservation of green spaces within urban areas. It is typical of such problem areas that the solution is only to a limited extent technological. A good part of the problem comes about because present economic incentives tend to be inimical to environmental protection. The point is made again, as so many times throughout the symposium--research toward redesign of the economic and industrial-agricultural system seems central to long-term resolution of environmental problems.

The response to this paper by Frank Sebastian includes a detailed report on progress in water reclamation, indicating both technological progress and economic viability of wastewater recovery. The message is clear--in emphasizing the needed systems research, stressed so many times through the symposium, do not overlook the technical progress on specific ameliorative measures.

Summary of Research Priorities

From these highlights of individual papers it is clear that certain themes stood out, and yet that there was a great diversity of viewpoints. As a brief summary of the research priorities identified, we might pick out the following six themes:

1. Environmental Systemic Interactions. This need was identified more strongly than any other. The whole system includes not only physical environment and institutions but also social, economic, and cultural beliefs and values. Modeling and research are needed toward understanding interactions in the whole agricultural and industrial production system, toward relatively closed, resource-frugal subsystems, and toward overall system incentives more compatible with preservation of the earth's basic chemical and biotic systems. A systems approach implies far more attention to the consumption phase of resource use--to reducing resource demands within the system, in contrast to present and projected research which is heavily weighted toward the supply phase. Since this in turn implies changes in lifestyles and a more frugal culture, research should involve public dialogue and education on central issues and policies.

2. Resource Usage Patterns. Numerous intermediate objectives involving subsystem modification were cited. Among them were reducing environmental impact of extraction and processing, improving use-recycle processes for materials, reducing energy use, reducing materials usage in fabricating and packaging, and improving durability and repairability of products.

3. Incentives for Controlling the Environment. Present economic incentives tend to conflict with environmental protection and enhancement. Short-term profit incentives and consumer fads mitigate against product durability and repairability and heavily discount the future.

Economic growth imperatives make it difficult to cut back on energy and materials use. The long-term resolution of our environmental situation may require major readjustment of this incentive system.

4. Critical Ecological Problems. Special attention needs to be given to critical problems where very long-term impacts might occur, global in nature, and where the set of outcomes is at least partially unknown and highly uncertain. These include the oceans, the stratosphere, CO_2 atmospheric centration, and nuclear waste. An ongoing research program, screening new materials and products and monitoring both environmental and social trends, is required to anticipate critical problems.

5. Applied Research and Technological Developments. Not to be overlooked in the emphasis on systemic problems are the specific research and technological advances that can reduce or ameliorate environmental impacts. Examples include low environmental impact technologies, recycling and waste processing technologies, materials substitution, and materials-conserving production and technology.

6. Environmental Monitoring and Assessment. Observation of both critical uncertainties and control programs should have high priority. Some scenarios for the future implicitly assume that the trends of the future will be more or less the trends of the past, and that the problems of the future do not differ in kind from the problems society has learned to deal with by technological prowess and appropriate institutional innovations. Another group, however, assumes that a combination of historical forces and physical limitations have brought society to a point of fundamental system transformation. The "limits to growth" thesis is but one form of this second argument, which says that the consequences of advanced industrialization will soon become so intolerable that a major restructuring of industrialized society may be inevitable. According to this view, partial system breakdowns accompanying this major societal transformation will become evident during the next decade or so. Because

uncertainty is so crucial in the accurate interpretation of societal problems, it is imperative that careful monitoring be instituted to determine as early as possible which track the society is on.

A more complete listing of recommended research areas, coming out of the symposium proceedings, will be found at the end of this report.

ACCOMMODATING THE NEW REALITIES

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ACCOMMODATING THE NEW REALITIES

William D. Ruckelshaus

I applaud the non-confrontal approach of this conference. I have concluded in the four and one-half years since EPA started, contrary to my every instinct as a lawyer and advocate, that in today's climate confrontation, and the adversary system we use to make so many environmental decisions, are in the last analysis too often causing bad decisions. These decisions, couched in terms of winners and losers by legislative, administrative, and judicial declaration, are not focusing enough on the public interest, but instead handing "victory" to one of the adversaries.

I applaud the SRI conference effort to avoid the endless and presently unresolvable debate over what the future holds for man. If we take as a starting point that we don't know what tomorrow will bring we can focus on what is advisable for man--and not spend endless hours debating what is inevitable.

The Environmental Protection Agency came into existence only four and a half years ago. It sometimes seems like four score and four years because a number of startling events have taken place in the interceding years. (My transfer from EPA to the FBI was the one of the more personally startling events.) Perhaps for all of us the time seems so long because our political/economic climate is so different from that prevailing at the start of the decade.

The year 1970 saw the first Earth Day and an explosion of public awareness and concern about the environment. As a people we came to have a better understanding of the biological, physical, and chemical interrelationships of life on this planet; and at the same time, naively, we

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also came to believe that environmental problems could be separated out and addressed by themselves. Congress and state legislatures passed some tough, demanding laws. The American people indicated at least preliminarily that they were willing to bear the costs needed to clean up the environment within the tight time frames set by their elected representatives.

An energy crunch featuring dramatically higher energy prices that contributed to worldwide inflation in concert with recession have changed the world economic and American societal conditions considerably. Tight public and private pocketbooks and the need to cope with unemployment have replaced the era of deep pockets for worthwhile projects we knew only a short time ago. These changed conditions, coupled with the erosion of public confidence in our institutions--both private and public--that began in the late 1960s and accelerated with Watergate, create a situation which many environmentalists feel poses a catastrophic threat to their goals. In response, some are attempting to stiffen or at least hold the line of our present environmental laws--rather than to accommodate the new realities.

I don't believe that our energy and economic problems are the harbinger of the end of environmental progress in this country, nor do I believe in reacting to these problems by increasing the inflexibility of our approach to environmental problems as some unfortunately--in Congress, executive agencies, and the environmental movement--are inclined to do. I would rather discuss the positive aspects of our current situation--and to put forth a perspective of the future I believe we should adopt to guide us wisely through the years ahead.

The great judge and scholar, Learned Hand, once defined "justice" as the "tolerable accommodation of the competing interests of society." I think we can--and should--use the concept of accommodating competing interests to guide our approach to societal problems such as environmental degradation, where in total only limited resources are available to meet virtually unlimited social demands.

In the early days of EPA we took a certain amount of satisfaction in the fact that we at last realized the problems of air and water pollution, pesticides, solid-waste and land use are interrelated and should not be addressed in isolation. In fact we created EPA, a new government agency, to attack these problems in a coordinated way. We sought to imbue the Barry Commoner concept "that everything is connected to everything else" in our public and private consciousness. But for all of our environmental farsightedness, we were at the same time exhibiting societal shortsightedness when we viewed the environment as unrelated to other problems.

It took long gasoline lines to bring us to the realization that the environment is not unrelated to other issues--and that the social fabric is like a balloon--if you push in at one point, it will bulge out at another. We are coming to better understand that we have only limited economic and natural resources for which there are virtually unlimited demands. We are coming to see that we cannot solve problems incrementally as if they were unrelated to other problems.

When I was the Administrator of EPA, I had mixed emotions about trying to solve the air pollution problems of urban areas like Los Angeles. It was clear that air pollution was really part of their transportation problem, which was part of a larger problem of the quality of life they really wanted. So our hopes for solving the air pollution problem were too optimistic. It turned out, in spite of the mandate by Congress that air throughout the country would be pure by June of 1975, that Los Angeles still has a major problem. In fact one of EPA's transportation control studies indicated that L.A.'s photochemical oxygen standard could be met by removing 92 percent of the automobiles from the highways. In January of 1973 I was ordered by the District Court of Los Angeles to provide a transportation control plan for Los Angeles or be held in contempt. So I went to Los Angeles and announced that 92 percent of their automobiles would have to get off the road. I admit I made the announcement at the airport and immediately flew out.

There is one great lesson we should draw from our efforts in the 1960s and early 1970s--that merely pouring out large sums of money or setting tough but unrealistic deadlines for a single problem will not necessarily result in the public interest being served. Not only is our own society more interdependent than in the past--so is the world. Droughts in the farmlands of Russia, and actions by tiny shiekdoms in the Mideast, can and do significantly affect our own cost of living and economic wellbeing.

I have the deep sense that the public in this country--in a visceral way--is more aware of the interrelationship of our societal problems including energy and the economy and the environment than is our leadership. Particularly, it seems ahead I think of the Congress. I was convinced in 1970, when we started to implement the new laws that Congress had passed, that while it was necessary to move forcefully and intelligently and with as much vigor as possible, there would come a time when the public would recognize that the problem was less one of advancing the technology than it was of what costs should be expended for what benefits. Unfortunately, many of the debates that were going on five years ago are still going on today at the same level of confrontation. Partly this is because of our inability to take advantage of the lessons learned and to explain these lessons to the committees of Congress. I would blame this mainly on the Watergate affair, in that the attention of the public and the Congress was riveted for two years almost exclusively on this problem. Now that we have reached the time where environmental laws need to be changed, we again find ourselves in a much more confrontational atmosphere.

There is a real need to take a dispassionate look at how competing social demands can be accommodated, and a need to abandon in many cases the practice of taking each problem to the point of confrontation. Confrontations may make great news stories--they encourage people to take sides and to focus on who is acclaimed "the winner." But if a problem is viewed as the environment versus the economy or the environment versus energy, with one or the other side winning, inevitably the public interest will lose because almost by definition the public interest is an accommodation. A number of the major issues I had to wrestle with during my tenure at EPA were depicted in the press as the "white hats" against the "black hats"--and score was kept of the number of supposed victories by each. It was difficult to get the message across to the press--and through them to the public--that the real question was not who "won" or who "lost"--but whether the action taken was in the public interest--whether it was a wise decision. It is discouraging to me that the media emphasis is even now on whether a decision is "tough" or "weak" and not on the essential question: Is it wise?

While not at the peak level of 1970-71, membership in major environmental organizations is holding fairly steady. And the polls show that the public continues to consider the environment to be an important issue. These are good indications. A Harris poll released in March showed that the American people ranked air and water pollution as the nation's third and fourth greatest problems--second only to inflation and unemployment. At the same time I believe that the public understands the need for reasonable accommodations with other pressing social problems, and expects that they will be made. How then are our major public institutions--Congress and the federal agencies--responding to the public will?

In the early 1970s Congress reacted to public pressure and passed a number of major environmental laws that embodied lofty goals and set stringent standards. In my opinion, like too many laws adopted by Congress, the environmental laws were adopted in isolation from other issues and were based on optimistic assumptions as to how much progress could be achieved in what time frame and what resources the society should commit to making that progress. Reflecting Congressional dissatisfaction with the past rate of progress, the new laws set out rigorous time frames for certain actions by both the public and private sectors that would require massive expenditures of money. But they gave EPA and the states relatively little flexibility.

EPA began to push its own bureaucracy, the states, municipalities and industry in the directions and at the speeds dictated by Congress. One of the early actions was to urge that utilities convert their boilers to use oil rather than coal to reduce the emission of sulfur oxides. No sooner was this shift of resources underway than our energy supply and economic conditions forced a reappraisal, and another Federal Agency is now ordering the switch from oil back to coal.

The measure of our institutions must be as much or more in their ability to respond and adopt to changed conditions as in their ability to design sound solutions for static problems. On this score we find that Congress has not only put in place too inflexible a structure for addressing environmental problems (a structure that in part requires economic commitments based on much rosier conditions), but the committees responsible for environmental legislation are still reluctant to legislate needed changes responsive to the new realities. That is why I have concluded that the public is far ahead of Congress in realizing that we cannot afford an unlimited blank check to clean up the air and water--and that progress that can be made must be considered against the social and economic costs that will be entailed, the resources that are available, and the ways in which those limited resources can most effectively be directed.

At first EPA had a fairly free hand in the course of implementing the Clean Air Act to de facto require the allocation of certain kinds of energy resources, particularly of low sulfur fuels, to certain areas of the country and to certain uses. But recently, Russel Train has been more constrained because the competing social concerns have become much more apparent. Now EPA must work and accommodate its goals relating to availability and best use of our energy resources with the Federal Energy Administration and the Energy Research and Development Administration. The environment is no longer the sole consideration. Reconversion of certain oil-fired boilers back to coal sharpened the conflict between competing interests of the agencies--and ultimately forced the required accommodation.

On the other various issues, the agency interests are similar to each other, and coordination of resources and responsibilities is important. EPA's solid waste office and ERDA will be working together on the development of solid waste as an energy source. With more projects like the Union Electric Plant in St. Louis where solid waste is burned to generate electricity, we are on the way to turning a disposal problem into a useful resource.

Similarly I gather that EPA, ERDA, and FEA are working together on how best to increase public awareness of the need and means of energy conservation. While their overall missions differ, in the energy conservation area, their interests and the public interest coincide. These are among the hopeful signs I see--that EPA recognizes it must come to grips with the new conditions and the new public mood. Agencies by necessity reflect public opinion--and they become more or less aggressive depending on public attitudes. This is not necessarily bad. It's the way a democracy is supposed to work.

The economic downturn clearly has made EPA pay more attention to the economic impact its regulations are having. This was happening before I left. Someone counted four times as many economists on our staff as ecologists. (That is not a statistic we normally published.) In the environmental area, like a number of other areas, tight economic conditions help the society become more efficient.

The theme of this symposium, "research needs to anticipate environmental impacts of changing resource uses," is giving you many knowledgeable presentations on the problems that EPA should be addressing. If I could add one message, it would be for EPA and indeed all Government agencies to continually look into the future to see what factors may inhibit the achievement of their goals, and to build in mechanisms to anticipate and accommodate those problems.

The emergence of the energy and economic problem can be beneficial if it aids us in organizing our legislative and administrative processes to accommodate new realities into existing efforts to solve problems--and to better recognize the interdependence of our world.

We should not underestimate the challenge to leadership that modern problems present. Environmental problems themselves are complicated and, when you add problems like energy scarcity and economic downturn, the equation is bound to produce answers that are unclear and controversial. No one will be satisfied.

In one sense what we need to restore confidence is more Mayaguez incidents. Someone swiped our boat, and we took it back. What could be clearer? I think the clear-cut nature of that problem and its clear-cut solution accounts for the overwhelmingly positive response to the American people to that incident.

But the new environmental realities are quite different. Someone or a group of someones has quadrupled the price of oil. What do we do about it? No one has a very good answer. This kind of problem contributes to the continued dissatisfaction and erosion of confidence in our government. Yet these are the President's daily problems. We should keep them in mind when we criticize leadership by him and other heads of state.

I don't believe we should view the new realities as a threat to cleaning up the environment--but rather as a challenge to accommodating a desirable social goal like clean air within the matrix of other social problems. If we lack the ability to adjust the pace with which we are addressing a given problem, or if we cannot accommodate our ultimate goal to a new consideration, we risk losing all our momentum toward solving that problem. Instead, we must be sure we are setting reasonable goals so that our progress will give us the confidence to go on to the next goal.

When I became the Administrator of EPA I believed very strongly that the challenge of the environment offered us an opportunity as a society to restore some of our confidence in our ability to deal successfully with a major complex problem. I continue to believe that this prospect is available to us in the environmental arena--despite high energy costs, changing resource demands, inflation and recession--if we carefully accommodate our goals to the new realities.

RESOURCE CHANGES, CONCEPTUAL DEVELOPMENT, AND RESEARCH NEEDS

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RESOURCE CHANGES, CONCEPTUAL DEVELOPMENT, AND RESEARCH NEEDS

John McHale

Resource changes not only impact our social structure, but also cause changes in perceptual and conceptual "worldviews" which accompany, and often precede, significant social, economic, and political change. One might initially suggest that our concepts with regard to resources, their impact on the environment, and usage of the term environment itself, have all changed radically in the past few decades.

Many of our principal resources were not even conceptually recognized as such a relatively short time ago. Aluminum was a scarce metallic curiosity, radioactivity a laboratory phenomenon, and many of our key metals were regarded as waste impurities in other ores. In this fashion, our range of useful resources is ultimately as we conceive it to be. It is dependent both on the state of our knowledge and the perception of our needs. These also change and interact with one another.

With regard to environment, two critical aspects of change have become dramatically visible:

The first is the explosive growth in our actual and potential capacities to intervene in the larger environmental processes. This is evident in the increase in human population, the transformation of the earth to human purposes, and in the range and amounts of energy and materials exploited. The scale of our human systems begins to approach magnitudes which can affect larger areas and relationships in the biosphere.

The second is the lag in conceptual grasp of this transformation and in the understanding through which we may manage its changes more effectively. One shift that has taken place is that "nature" or "environment" is no longer something to be conquered--but protected and conserved. We begin to recognize that human decisions not only determine environmental conditions but most other aspects of the human condition.

Attention has been focused primarily on the impacts of technology on the physical environment. More recent thinking indicates the prior importance of "institutional" impacts; i.e. that the crises are not *in* energy, *in* technology, *in* food supply, *in* the environment, and so forth. They are all institutional crises. They are the results of specific values, attitudes, and institutional arrangements through which these activities are conducted. Many of these economic, political, and other policies have been expedient and practical in the short range. It is only now when their visibly dysfunctional effects have become apparent in the longer range that they emerge at crisis levels--but still with least attention to their real causal origins.

Given the nature of the crisis, many people have accepted, somewhat uncritically, a revised set of neo-Malthusian premises. Human growth within a finite earth system is viewed as leading almost inevitably to catastrophe within the next half century. Many recent proposals emanating from this viewpoint contain explicit, or implicit, abnegation of continued technological and material growth, which is viewed as the major factor leading to critical imbalance. Some advocate the return to more frugal, and even more pastoral modes, as ways of avoiding the crisis.

But while recognizing the need for more rational growth policies, there is no necessary or essential connection between the development of advanced technologies, the material improvement of living standards, and deteioration of the natural environment.

There is no absolute relation between high production and consumption with high environmental impact. Many of the richer countries in the world have significantly "cleaner" living environs than the poorer. The severe problems of local and worldwide pollution are due to lack of foresight, inadequate planning, and mismanagement. They are institutional and regulatory in origin rather than absolutes.

There is, again, no direct linkage between population growth and high environmental pressure. Many of the richer countries with high population densities have significantly less impacted environments than the poorer. In terms of population growth rates, most future growth will be in the lesser developed countries whose material resource usage is still relatively small--whereas most anxiety is felt in the developed countries whose populations are stabilizing and whose resource consumption could, and in some cases is, leveling off. Where environmental impact is still high in the latter it is due to wasteful resource management, planned obsolescence of products, and overstimulation of demand, among other factors.

As we shall discuss, more balanced growth with less resource demand and high technological development may be accommodated with low environmental impact.

There are a set of more specific points which I have been asked to touch upon. One set relates to resource availability, new technologies and life style changes, and how these may affect EPA policies. The resource availability question is directly related to technological development.

Energy is the most obvious issue here and yet the most clouded one. We have reiterated emphasis on the energy crisis but more clearly this is not an energy but an oil crisis--and then not a crisis in terms of actual shortage but in terms of price and availability. It is a crisis that has been allowed to occur in terms of a preferred fuel use for convenience, profitability, and expediency.

In terms of resource supply, the real problem may be a return to oil surplus due to extended exploration and the use of oil sands and shale--thus encouraging more profligate use of a potentially more valuable source of petro-chemicals, medicinals, plastics, and even new food sources, than of a material to be wantonly burnt up.

What are the prospects for adequate energy supply in the face of increased demand?

The conventional mode is to treat this in terms of reserve capacity against current and extrapolated rates of consumption. For oil and natural gas, these are conservatively estimated to vary from 30 to 50 years, for coal upwards by magnitudes of 200 to 500 years. No one knows exactly what reserves exist, and figures are constantly revised upwards. Rates of consumption have about the same confidence level as indicators.

Nuclear fission power obviously extends this capacity but has greater environmental hazards in terms of operation and radioactive waste disposal.

How does this fit with longer range EPA policy? Leaving aside the obvious encouragement of alternative energy sources, one key factor in short and long-term adequacy is efficiency of energy use. Wasteful energy uses are not only uneconomical but usually have high environmental impacts.

The overall efficiency of world energy use is between 6 and 8 percent. With due assessment to improvement of efficiency at every level of conversion, storage, distribution and end use we could probably double such a figure to between 10 and 15 percent overall. That is we could have twice as much power from conventional sources at the same energy cost--with lower environmental cost.

The variability of efficiency among the industrialized countries illustrates this. For example, the energy required to produce an arbitrary unit of Gross Domestic Product varies from 1.0 in Sweden to 1.3 in Japan and 1.9 in the United States. That is, the United States uses almost twice as much energy to produce the same unit of wealth as Sweden.

What is the feasibility of increasing efficiency? Even with little explicit attention to this, in the United States over the past 50 years the amount of energy input per capita unit of GNP in the manufacturing sector has declined steadily with a corresponding increase in overall GNP. The great increase in per capita energy use has been in transportation, service and domestic sectors particularly marked by low efficiencies in conversion and end use.

Increase in efficiency of energy use is, therefore, an obvious target for EPA research priorities--requiring attention to alternative energy sources. Many of the latter are less environmentally impacting, and by utilizing agricultural, industrial, and urban wastes may decrease environmental problems in other areas. They are, of course, poorly funded in research and development due to institutional inertia and vested interests in more conventional sources.

When we turn to material resources the picture is obscured in much the same fashion as energy. There is all sorts of loose talk about resource shortages, needs to restrain production and restrain technological development.

By traditional practice, most of our data on metals and minerals use are biased toward primary extraction and processing. Beyond primary production, it is progressively difficult to assess materials in use per sector or product performance. Rates of use and consumption figures usually do not take into account the fact that we do not consume materials in use. We use them in various combinations over time for different purposes.

Most of our metals are re-available after "use-lifetime" cycles in products of from 3 to 25 years. In many cases, the recycling process gains in efficiency of performance over the primary extraction cost of the material--plus the fact of avoiding the large amounts of waste overburden in primary extraction. We have, however, very few models of the use, recycle process which have been developed specifically for the reduction of both performance and environmental costs. Adequate large-scale modeling of this type is an obvious EPA priority.

This speaks not only to environmental and resource conservation but also to the reserves question in materials. Conventional reserve estimates are considered only in terms of unmined resources. In effect, however, our gross reserve includes all materials in use, in "junk" stockpile form as well as in existing structures and products. Cumulative production over time is, therefore, an index of reserve and in some cases is from one-third to almost three times our estimated recoverable reserve for many major metals.

The question of materials (like the energy question) is not one of materials scarcity but of the sets of conventionally preferred use arrangements. In economic as well as environmental terms, it speaks to the need for more comprehensive long-range research into the following two primary areas:

(1) How We May Use Our Materials More Efficiently in Terms of Performance per Resource Unit Used.

- More systematic reuse and recycling practices. It is estimated that approximately 55 percent of all copper put into use can eventually be recovered. As against new copper mined with increased volumes of waste rock (at approximately 400 tons per ton of usable copper), efficient reuse would double both conservation and economy if organized on a larger scale.

  In effect we need to reorganize our materials extraction and use system in more rational terms to close the waste, residuals and by-product loops in more efficient fashion. At present each section of the industry operates in relative autonomy--extractive, primary processes, secondary manufacturers, marketing, and end-use. Then there is a longer gap to the scrap industries. The more rational mode would be a more continuous systemic process with ongoing environmental assessments at each stage in the process.

- At the production and use end of the materials cycle, the obvious direction is build the scrapping and re-use function in at the beginning. That is to design products for longer life cycles wherever appropriate, to design in their disassembly and recycling procedures, and to prepare anticipatory schedules for the recovery stages of their various materials. This system has been partially introduced in the manufacture of military aircraft where costly alloys have their constituent composition stamped on the component to aid recovery on scrapping.

As we began our discussion with the need for reconceptualization of the overall resource position, so we now need to reconceptualize and redesign our industrial system as a potentially regenerative one.

(2) Ranges of New Materials Coming into Use Require More Comprehensive Environmental Attention. This need not always be negative, in terms of their projected impacts but may also be turned toward their potential for replacement and substitution for more environmentally impacting uses. For example, as older materials such as steel give way to lighter metals, to plastics and composites, this may also afford gains in economy and performance with equivalent reductions in environmental costs. Man-made fibers already off-loaded agricultural land from vegetable fibers, increased food acreage and potentially reduced environmental pressure for more diverse land use.

Again this is an area of environmental research which is presently accorded only piecemeal and relatively negative attention. More comprehensive long-range assessment policies are patently required. The range of developed and potential material substitutions may not only enhance required supply levels but also have less impact on the environment.

Technological development is obviously a crucial factor in the environmental aspects of energy and material resource uses. The problem here is that we tend to lump together all the different phases of "industrial" technology. We may distinguish at least three major phases of industrial development with different sets of typical resource uses, environmental impacts, and related socioeconomic changes.

The first phase encompasses the heavy industry developments incident upon the later stages of the Industrial Revolution--typically steelmaking, railroads, automobiles, electrical generation, and so forth, based on the fossil fuels. This type of industrial practice is highly resource depletive, with low performance per input of energy and materials, and has gross environmental impacts through its effluents and other by-products. Although it still constitutes the industrial base of many societies, it is partially obsolete in its plant, production/consumption practices, and supporting materials policies.

The second phase of industrial development trends toward the light metals and plastics associated with the development of air transport, aerospace, and computers--and the emerging set of new electromagnetic spectrum industries, i.e. electronics, telecommunications, and nuclear energy which developed after World War II. This phase, is by comparison, non-resource depletive, extremely economical in energy use and has a much lower impact on the environment. Its advanced technological forms trend toward ephemeralization through their decreasing use of materials and energy per function, and their successive microminiaturization of components.

The third phase might be characterized by the development of new ranges of metallic and nonmetallic composites and reinforced materials for structural purposes coupled with more sophisticated electronic and electrochemical processing and the emergence of biotechnical developments, e.g., the resurgence of industrial microbiology and bionic engineering, the more efficient use of microbial populations to produce energy, food and process materials, and the development of new ranges of alternative energy sources.

In practice of course, these phases overlap and have different rates of growth and development. In the advanced societies they are also paced by changes in social and economic organization, in the balance of production and services, and by internal shifts in manpower and resource requirements. Hence the shift from the first to the second and third phases of such development is often phrased as from industrial to post-industrial society--meaning really a shift to a different kind of industrialization.

One key factor in this shift, of relevance to our theme is that, with the fusion of information and communications technology, information (or organized knowledge) begins to emerge as the unique resource capability. Information as basic resource has certain unusual properties:

- All other resources and technics are ultimately dependent upon information and knowledge for their recognition, evaluation, and development.
- Information as a social resource is not reduced or lessened by wider use or sharing like material resources--rather it gains in the process of distribution and exchange.

Where previous resource bases such as raw materials and energy were, by comparison, scarce and depletive, information and knowledge are inexhaustible. The enlarged environmental awareness in itself may be largely due to increased capacities to perceive, monitor, and evaluate environmental changes incident upon these new information and communications capabilities. Certainly the attitudinal changes towards the environment were greatly aided by the electronic media.

The above review does not absolve uncontrolled technological growth as a major factor in environmental deterioration nor does it advocate technological deterioration. It merely stresses the need for more adequate conceptual and policy frameworks for differentiating and evaluating the impacts of technology. More immediate measures lie with appropriate institutional change, with more stringent economic disincentives to waste and pollute, and with more rigorous socioeconomic and technological assessment.

Our current assessment procedures need to be expanded in several ways and are thus candidates for the longer range research needs of the EPA.

(1) The need to include institutional and policy assessment. That is, to recognize that the environment is not only modified by physical actions but by our ideas, beliefs, and value systems--social, economic, cultural--and the ways in which they operate to influence policies and environmental decisions even more than material techniques.

(2) That the industrial assessment process should be conceptually reorganized to consider both agriculture and industry together with their product and service components as a whole system. It should encompass not only industrial uses, residuals, and pollutants but also agri-industry equivalents and how these are related to domestic materials, garbage, and effluents. This would furnish a beginning description of our overall environmental transactions as the external metabolic system of society. We have accumulated considerable systematic knowledge about the flows of energy and materials in our internal metabolism, but our conceptual framework of our external metabolic flows is singularly inadequate.

(3) All such assessments should be oriented towards the longer range of the next 30 to 50 years (some perhaps beyond) and should be prospective by nature. Our tendency thus far has been to restrict attention to those impacts that have already occurred rather than anticipating the possible impacts and cross-impacts of processes before they are introduced.

Moving to the life style changes which may be underway and which might influence environmental policy, one can return provisionally to the post-industrial shift hypothesis.

This carries with it certain suggestions about growth, consumption, and quality of life which may be important. It is generally assumed that, in the more advanced societies, material expectations and demands for personal consumption will continue on an exponential curve--thereby sustaining gross resource depletion and environmental deterioration. The evidence seems otherwise. It may be suggested that as standards of living rise beyond sufficiency, we get satiation levels of demand. Wants may be artificially stimulated beyond this point but, as advertising revenues show, this is a costly process. The tendency is not toward just more products and more things but toward wider ranges of alternative choices of products and toward greater access to shared services.

Material satisfaction in terms of individual consumption peaks out below maximal satiation and then finds expression through progressively dematerialized and, eventually symbolic means of satisfaction.

At a low income level, the material and symbolic goal may be a large resource-hungry automobile. As such goals become more easily reachable, they tend to transform into an interest in smaller high-performance cars thence to a recreative and "aesthetic" interest in speed or driving generally. Where food is scarce, being fat has high social status. In rich societies today it is the reverse--foods are consumed for their low caloric value and some become merely symbols of consumption rather than material actuality.

There is an accompanying value shift observable where people begin to pursue styles of life and goals for personal growth which move away from the energy-intensive, materially costly and conspicuous consumption of the earlier industrial society toward concerns with the meaning and quality of life experience. The expansion of shared amenities such as national parks, clean waters and beaches, becomes important--even where the individual may not use them, he or she will subscribe to their collective availability as a drawdown on the public purse.

Overall this kind of social shift, accompanied by the technological changes already described, suggests that even the "growth" requirements of more people can be satisfied with less per capita resources and less environmental impact. We should not, however, assume some invisible hand at work guiding these trends so that it all comes out for the better! Many of the positive aspects of these changes have to be anticipated and aided rather than merely observed.

Neither may we assume that most current policy directions and leadership will bring them about. Indeed many of the key change issues have emerged not from leaders and policies but from issue-oriented citizen groups in the society--for example, environmental conservation, consumerism, and quality of life issues surfaced in this way before they were sanctified by policy attention. This suggests that a key function for EPA may also be the closer analysis and oversight of social trends, attitudinal changes, and value orientations with their appropriate long-range projection in terms of environmental policies.

In the larger sense, we refer here to the longer range social and political constraints that may affect EPA decisions. Very often such constraints on the wider demands for a better environment emerge not from any broad consensus of the society but from the specific interest groups who have the power and lobbying pressure to influence and constrain decisions far in excess of their representative numbers.

There is no fast answer to how a better balance of interests might obtain. The paradox often exists that those who have such power to influence policies derive that power from public resources such as federally leased lands, direct and indirect public subsidies, and various other means which flow ultimately from the citizen's purse. Many of our best environmental policies have been pursued in the face of opposition from those with short-term political mandates or concerned with the most economically expedient exploitation of environmental resources. In general, the emerging debate in this area may be characterized as a conflict between the politics of longer range social requirements and the shorter range expediencies of "business as usual."

Again, the balancing of these competing interests, which may aid or constrain appropriate long-range policies, may well be a focus for EPA research. Certainly one component may be vital here--communication and contact with the larger publics Information on both the key issues and on the intricacies of specific policies is often restricted to those special interest groups who may be opposed to their consequences. The EPA should forward more continuous appraisal and communications functions both with expert groups acting in the public policy interest and with the wider citizenry directly and through its various associational groupings.

In concluding, I have been asked to identify some priority research topics which the EPA should undertake now. I have mentioned a number of these in dealing with various topic areas of my brief. In order of priority they may be summarized as follows:

Generalized Program Priorities

(1) The development of a more comprehensive conceptual framework for environmental concern. This would include the systemic interrelationship of resource usage patterns, technological development, and socioeconomic change.

(2) Larger scale modeling of the industrial, agricultural, and urban systems. These need not, and perhaps should not, be initially quantitative in cast. It probably calls more directly for a broad "taxonomic" synthesis and mapping of

the interactive components in the overall system and projections of alternative relationships and tradeoffs.

(3) Expansion of the assessment process to include both technological and institutional assessments oriented specifically towards prospective appraisal of their longer range consequences and cross-impacts.

(4) Need for a balance of more integrative work with reductionist directions, i.e., more synthesis to pace analysis, or to combine analytical results into larger policy oriented, long-range, frames of reference.

Specific Research Priorities

(1) More efficient and less environmental impacting resource usage. This would involve detailed energy and materials budgets for specific product and service flows, oriented towards increasing performance per unit of invested resources and the reduction of wastes and residuals.

(2) An investigation of the redesign of major product and appliance groups towards possibilities of longer life, built-in procedures for scrapping and reuse and higher efficiency of operation and maintenance.

(3) A new materials assessment program in terms of feasible substitutions both for improved resource performance and environmental impact. This would obviously include the screening of new materials and products for their negative effects on the environment.

(4) The analysis and projection of longer range social needs and trends. This would encompass the emergence and identification of changes in attitudes values and life styles in the society and their projected consequences for changes in environmental policy.

(5) Public communication and consultation. The design of better procedures for public policy appraisal by expert and public groups: increased information dissemination on critical issues and policies with wider exposure to public debate via the media.

We may note that these summarized priorities are obviously interlinked. The specific recommendations fold in as components of the generalized program priorities. It should also be assumed that many of these topic areas will require a global context for their more realistic assessment rather than being confined only to the U.S. national society postures.

THE EMERGING SITUATION FOR RESOURCES--AN EXTRAPOLATIVE VIEW

Theodore J. Gordon
The Futures Group
Glastonbury, Connecticut

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THE EMERGING SITUATION FOR RESOURCES--AN EXTRAPOLATIVE VIEW

Theodore J. Gordon

Introduction

Both the drives for increasing economic output and for increasing world population require continually increasing raw material use. The world per capita mineral consumption rate quadrupled over the past 25 years.[*] Assume for a moment that a similar rate increase will hold over the next 25 years. In that same interval, world population will about double, Therefore, by combining these two forces, by the year 2000, the world as a whole may increase its present mineral consumption by a factor of eight or so. Failure to achieve this growth will mean that developing countries will not be able to achieve their current economic goals.

The dilemma implied by this tremendous growth rate is illustrated in Figure 1. Since 1945 annual world production of the indicated mineral has doubled every seven or eight years, while in the United States the production doubling rate was approximately 25 years. In 1945 the United States consumed about 60 percent of the world total for the minerals shown; by 1971, primarily because of the growth of consumption of other nations in the world, this figure had fallen to 16 percent.

This huge increasing demand for raw materials has enormously important consequences. The economic condition of the United States depends,

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[*] Eugene N. Cameron, "U.S. Contribution to Mineral Supplies," Mineral Position of the United States, 1975-2000, p. 21 (Madison, Wisc., University of Wisconsin Press, 1973).

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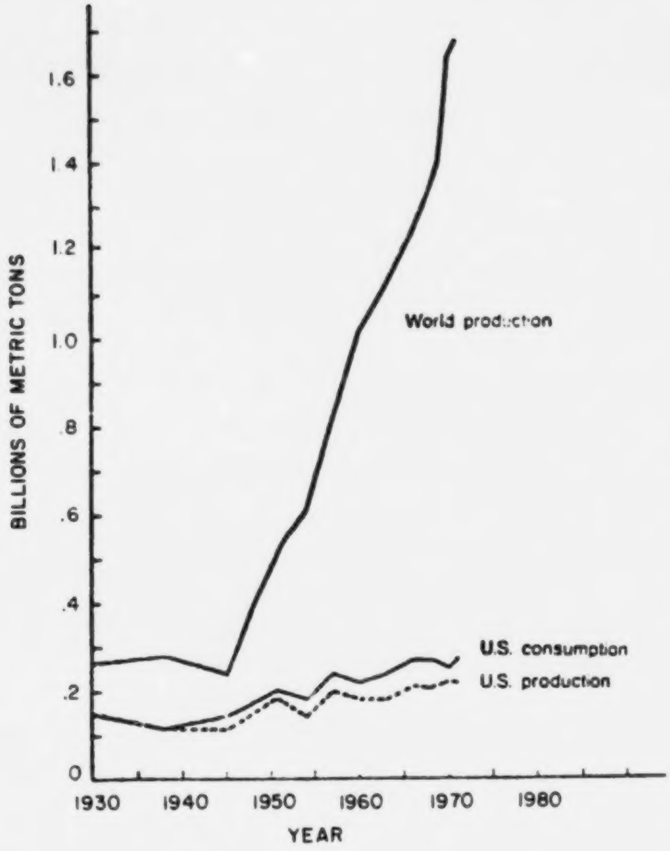

Data compiled at the University of Wisconsin by Kenneth D. Markart and E. N. Cameron, from U. S. Bureau of Mines, MINERALS YEARBOOK AND COMMODITY DATA SUMMARIES. From MINERAL POSITION OF THE UNITED STATES, 1975-2000, p. 19 (Madison, Wisc., University of Wisconsin Press, 1973.)

FIGURE I. 1930-1971 WORLD PRODUCTION AND UNITED STATES PRODUCTION AND CONSUMPTION OF EIGHTEEN MINERALS (Iron Ore, Bauxite, Copper, Lead, Zinc, Tungsten, Chromium, Nickel, Molybdenum, Manganese, Tin, Vanadium, Fluorspar, Phosphate, Cement, Gypsum, Potash, and Sulfur) in large measure, on the continued availability of reasonably priced, economically important materials. With growing competition for these resources on a world market, our economy becomes more dependent on world economic and political conditions. To the degree that countries depend on imports, opportunities abound for OPEC-like cartels. The environment is likely to be severely stressed in an effort to produce and dispose of the demanded materials. And, perhaps most disturbing of all, the depletion of some economically viable resources is possible in our lifetime.

These factors have led to the argument that consumption must be curtailed, that society must somehow be reoriented toward other measures of achievement, that nonindustrial models and goals must be found--not only for the United States, but for all nations--and that, in fact, many nations of the world are in the midst of such a transition currently. This is one plank in the "limits to growth" platform.

The central point of the "limits to growth" argument is irrefutable; exponential growth of world population and resource-depleting production must ultimately end--the issues are when and how.

In this paper I answer "neither the growth of population or resource depleting production is likely to end very soon." The difficulty of influencing population growth rate is well known. Even if the world birthrate dropped markedly and quickly, the world population would almost certainly reach six billion by 2000 (versus four billion currently). To imagine a very rapid transition from the current consumption and economic growth orientation to society based on new cultural values (or if not new values than at least a value structure based on vastly different priorities) is difficult indeed. The system inertia is too high; the lessons of the culture too strong; the levels of expectations too high in the United States and elsewhere. The reward structure of corporations, the expectations of people about what constitutes a "good life," the popular images of "progress" and "status," the whole notion of Gross National Product (GNP) and GNP growth as a measure of achievement all suggest that our present culture, and indeed the culture of all developed nations, requires not only consumption but increasing consumption.

This consumption-oriented growth-oriented culture is not unique to the United States; it is the culture of industrialized nations. Furthermore, many developing countries form their economic goals on the model of the developed countries. In developed countries economic growth is apparently a necessity, at least for the short term, to keep unemployment low, to remain competitive internationally, to satisfy system imperatives of their complex economic structure and, some economists argue, to permit less affluent individuals to achieve higher living standards either through transfer payments or through other redistribution mechanisms. In developing countries growth in output is seen as a birthright, a path to affluence, well chartered by the United States and other nations.

So we are on a collision path. Reserves are needed in increasing amounts as a result of growing economies and populations; yet providing them will be chaotic, perhaps disastrous.

Perhaps expectations and values and economic structures can change fast enough, but I doubt it. Where then does that leave us? Sorely in need of more time. Technology, informed and sensitive technology, mechanical as well as social technology, can help buy time and mitigate the impacts of growing mineral use. We have little choice but to define what would be helpful and to pursue it.

In this paper I plan to:

- Review some of the reasons for the chaos.
- Describe the slow transitions which are apparently already underway.
- Propose some technological and policy alternatives that might improve the situation.

Some Reasons for Chaos[*]

The rising world demand for raw materials suggests that the United States, for the first time, is likely to face a situation of continually rising, unpredictable prices and uncertainty of supply of many materials. To meet its needs, the United States has to depend increasingly upon imports of certain materials--domestic production has lagged behind demand (see Table 1).[†]

Dependence on imports seems almost certain to grow. As shown in Figure 2, under the assuumption of continued economic growth in the United States, reasonable projections indicate that by 2000, imports will account for more than 90 percent or more of all the chromium, tin, titanium, platinum, beryllium, aluminum, and fluorine the country consumes.[‡]

A paradigm for forecasting future OPEC-like situations might be to identify key materials used by industrial nations which are concentrated in a few other nations that could be linked politically. The paradigm becomes particularly strong if the recipient countries do not have access

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[*] Some of the material in this section is drawn from: L. Heston and H. S. Becker, Focal Points in the Future of Food and Mineral Resources, Report 151-46-10 (Glastonbury, Conn., The Futures Group, July 1974), and T. J. Gordon, Shortages and Their Implications for American Business, Report 132-59-01 (Glastonbury, Conn., The Futures Group, March 1974).

[†] Material Needs and Environment Today and Tomorrow, Final Report of the National Commission on Materials Policy, pp. 9-8 (Washington, D.C., June 1973).

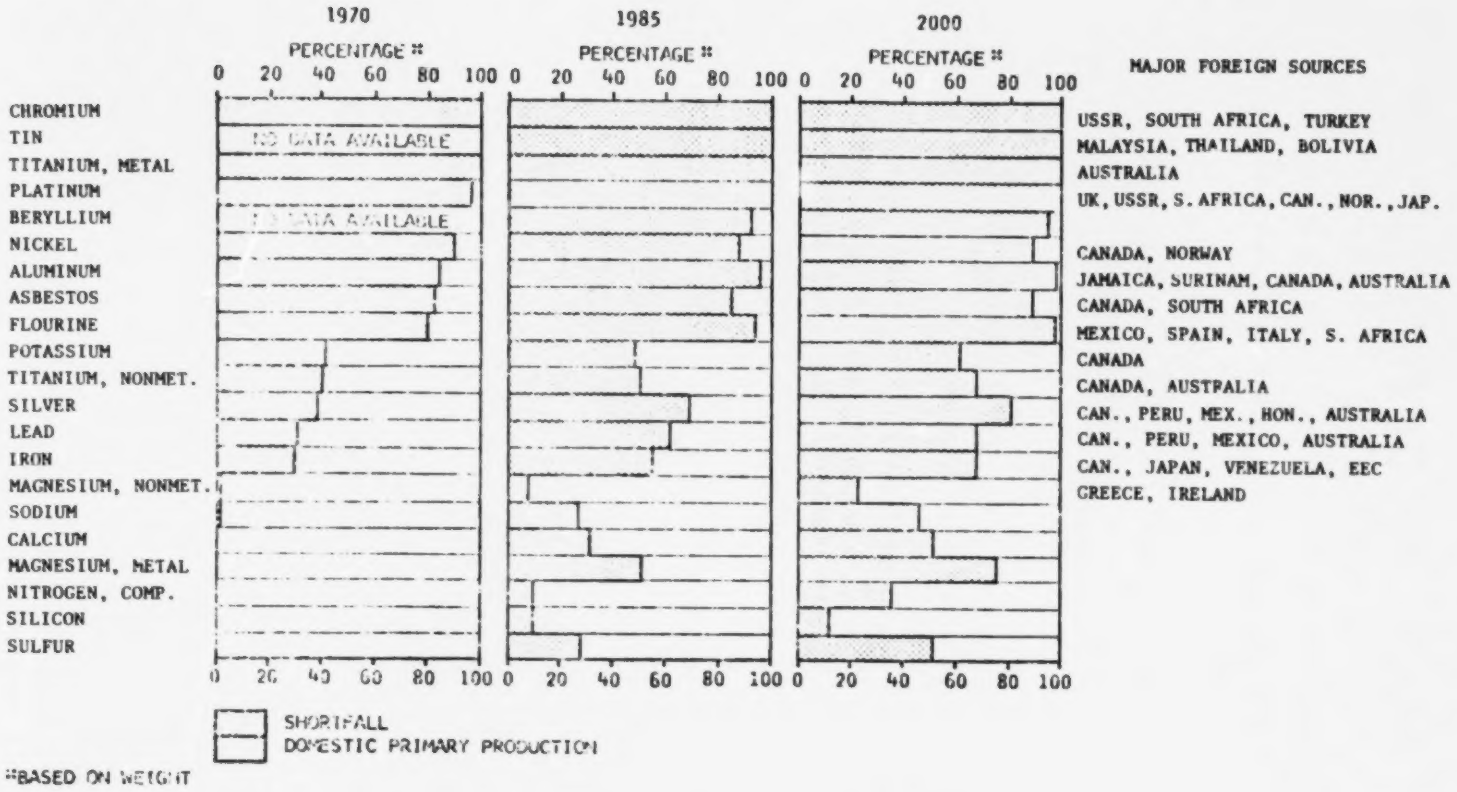
[‡] U.S. Department of the Interior, First Annual Report of the Secretary of the Interior, under the Mining and Minerals Policy Act of 1970 (P.L. 91-631), p. 63 (Washington, D.C., 1972) and Material Needs and the Environment Today and Tomorrow, Final Report of the National Commission on Materials Policy, pp. 2-25 (Washington, D.C., June 1073). (Hereafter called U.S. Department of the Interior, First Annual Report and Material Needs.)

Table 1

CHANGING UNITED STATES RELIANCE UPON SELECTED MATERIALS FROM ABROAD

	Imports as a Percent of Total U.S. Consumption		
Material	1950	1970	Change
Aluminum	71	86	+15
Copper	35	8	-27
Lead	59	40	-19
Mercury	92	38	-54
Platinum	91	98	+ 7
Tin	100	100	--
Titanium	32	47	+15
Zinc	37	60	+23
Iron ore	6	14	+ 8
Chromium	100	100	--
Cobalt	92	96	+ 4
Columbium	100	100	--
Manganese	77	94	+17
Nickel	99	91	- 8
Tungsten	80	40	-40
Petroleum	8	22	+14
Natural gas	0	3	+ 3
Timber	11	8	- 3

Source: Material Needs and Environment Today and Tomorrow, Final Report of the National Commission on Materials Policy, pp. 8-9 (Washington, D.C., June 1973).



SOURCE: U.S. Department of the Interior, FIRST ANNUAL REPORT OF THE SECRETARY OF THE INTERIOR, under the Mining and Minerals Policy Act of 1970 (P.L. 91-631) (Washington, D.C., 1972), p. 63; and MATERIAL NEEDS AND THE ENVIRONMENT TODAY AND TOMORROW, Final Report of the National Commission on Material Policy, pp. 2-25 (Washington, D.C., June 1973).

FIGURE 2. DIFFERENCE BETWEEN U.S. MATERIAL SUPPLY AND DEMAND

to economically viable substitutes. Figure 2 presents some possible groupings.[*]

It does not appear that the world will be depleted of any major mineral resource in this century. This statement is based on the following assumptions:

(1) World rate of consumption of raw materials will continue to increase exponentially. Projected growth rates run from 1.1 percent per year for tin to 6.4 percent per year for aluminum.

(2) Known reserves will increase by a factor of five before the turn of the century. This assumption is intended to capture the effect of price elasticity: as the resource nears depletion, its price will rise; as prices rise, there is additional incentive for exploration and recovery of previously marketable resources. This "factor of five" assumption could, of course, be wrong.[†]

Using these preconditions, the length of time remaining before depletion of important nonrenewable natural resources in the world can be computed. While it is true that these figures indicate depletion of important materials will not occur in this century, they demonstrate, nevertheless, that depletion is near. As depletion nears, we can expect increasing prices, intensified arguments for resource conservation, hasty searches for substitute materials, and increased government regulation of the use of material. All of these forces are inflationary and will cause balance of payment difficulties as well as fluctuations in the value of currency.

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[*] U.S. Department of the Interior, First Annual Report and Material Needs.

[†] These assumptions and the figures shown in the text are from Donella H. Meadows, et al., The Limits to Growth (New York, Universe Books, 1972). In their computations, the known global reserves were derived from U.S. Bureau of Mine estimates.

Resource	Remaining Years to Depletion*
Aluminum	55
Chromium	154
Coal	150
Cobalt	148
Copper	48
Gold	29
Iron	173
Lead	64
Manganese	94
Mercury	41
Molybedenum	65
Natural gas	49
Nickel	96
Petroleum	50
Platinum group	85
Silver	42
Tin	61
Tungsten	72
Zinc	50

Estimates of mineral resources change over time. The reserves are reduced by production, as well as by decreases in prices, increases in costs, increased availability of substitute sources, or government regulations that restrict the production and/or use of different materials. On the other hand, reserves may be enlarged by new discoveries and by new technological or economic developments making it feasible to produce from deposits that previously had proved uneconomical to mine. Therefore, the future of mineral resources supply in the United States depends not only on presently minable deposits already identified, but on potential resources as well; these resources include similar quality deposits as yet undiscovered and lower quality deposits which may prove worthwhile at some point in the future.

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*U.S. Department of the Interior, First Annual Report and Material Needs.

If shortages developed in materials for which indigenous but untapped reserves exist, they would undoubtedly be developed. Vincent E. McKelvey, Chief of the United States Geological Survey, believes that at higher prices, most of our mineral needs could be met through the turn of the century at least, by using materials which lie within our borders.* However, among materials not to be found in quantity in the United States are tin, manganese, and chromite. Furthermore, developing these resources would undoubtedly have significant environmental and political ramifications. The environmental implications are obvious; as for the political, we already hear dissatisfaction expressed by a state rich in one or another mineral, which feels exploited when it must "export" the mineral at the expense of its environment to satisfy the need of another state. To put it more precisely: why must Louisiana export its natural gas when the state itself is in short supply? Why should Montana suffer strip mining when the coal finds its use out of the state? The arguments are reminiscent of those used by developing countries.

The Transition in Progress

There is an inexorable relationship between the size of an economy and its consumption of materials and energy. Certainly there is some "scatter" which represents more or less efficiency or special condition, but by and large, the correlation between consumption and output is strong. This is illustrated for energy consumption in Figure 3. Some

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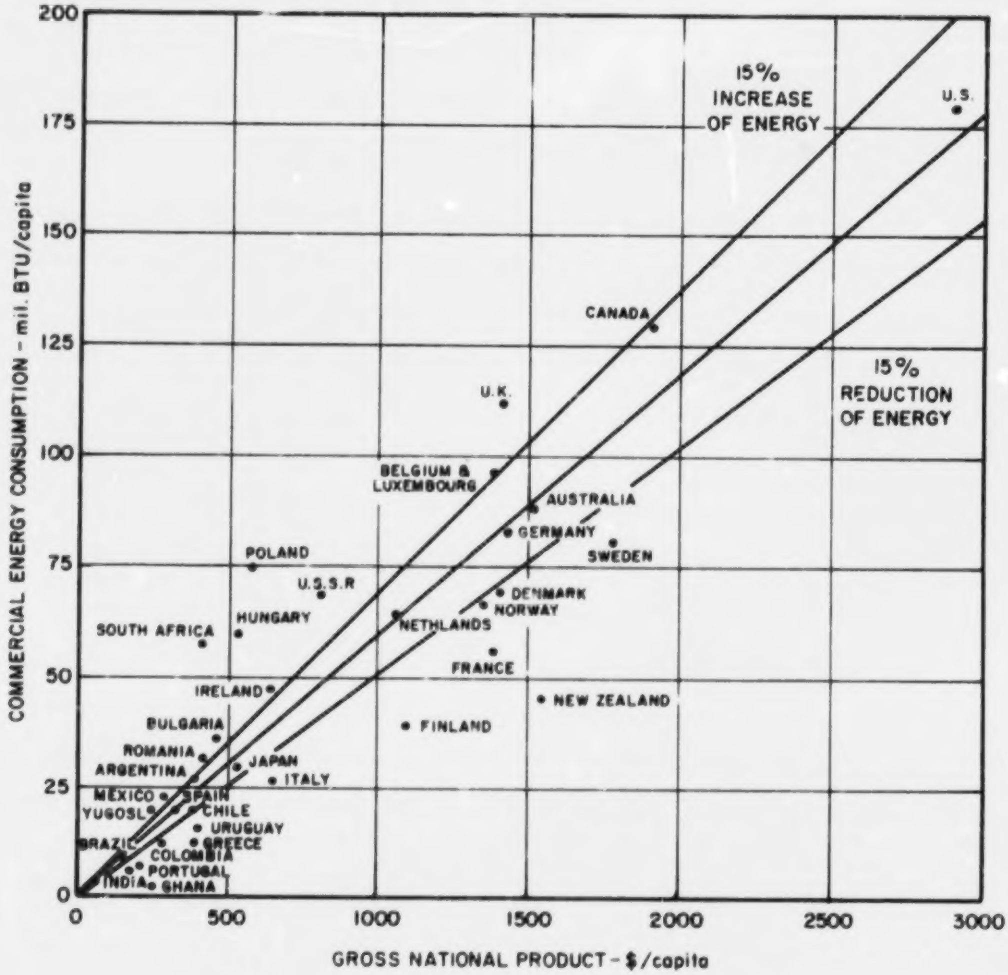
*"Raw Material: U.S. Grows More Vulnerable to Third World Cartels," Science (January 18, 1974).



Source: E. Cook, "The Flow of Energy in an Industrial Society," SCIENTIFIC AMERICAN (September 1971), p. 142.

FIGURE 3. RELATIONSHIPS BETWEEN ENERGY AND GNP (1968)

of the variation around the trend line in this figure can be accounted for by differences in weather and lifestyle preferences, particularly with respect to transportation. Such relationships offer at least a clue about how much might be saved through conservation without requiring massive economic changes in a country; targets of more than 15 percent would probably be very difficult to achieve.

Despite the strong correlation between input mineral requirements and economic activity, there are some indications that things are changing. First of all, we are indeed in the midst of a transition to a more service-oriented economy. A smaller percentage of the labor force is and will be engaged in agriculture and manufacturing; the service sector--including government--is growing. Within ten years or so, only one worker in four or five (versus one in three currently) will be in manufacturing; fewer than one in 20, in agriculture. Such an economy will be less energy and material demanding.

Secondly, for some materials at least, long term efficiency-improvement trends seem to be in progress. Since the early 1920s the U.S. energy/GNP ratio has been in a falling trend, as more intensive use of energy was offset by increased technical efficiency. From 1966 through 1970 the trend reversed itself and the ratio moved steadily upwards. This had alarming implications for the future, and there has been much speculation that if the rise continued it would lead to even more drastic energy shortages than had been predicted. In 1971 and 1972, however, the ratio resumed its downward direction. Both the National Petroleum Council and the Bureau of Mines of the U.S. Department of the Interior* anticipate that the ratio will continue to fall in the future.

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*Dupree, W. and R. West, U.S. Energy Through Year 2000 (Washington, D.C., U.S. Department of the Interior, December 1973).

Figure 4 depicts this history and a forecast of the project development of the ratio which was made recently in a study by The Futures Group.*

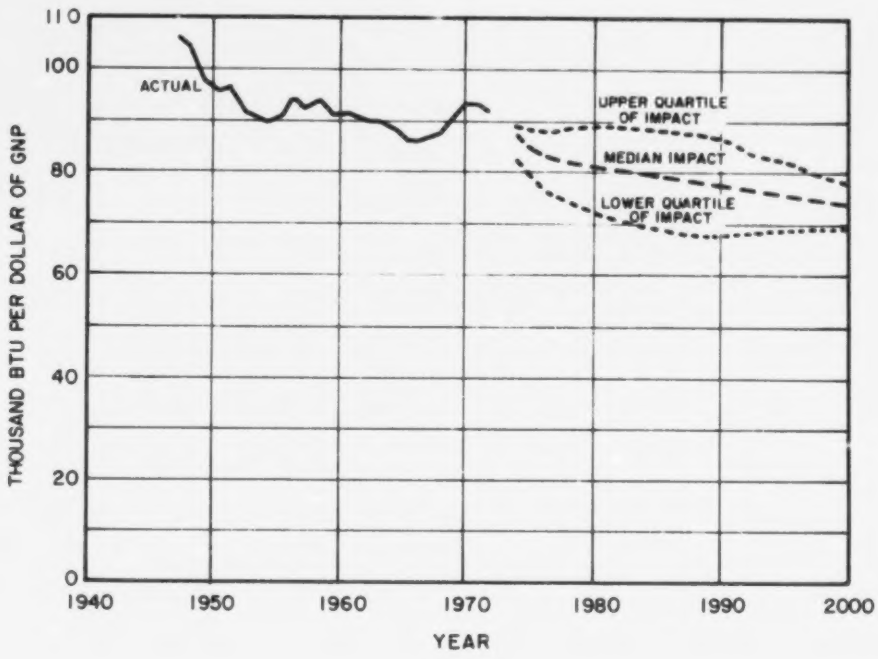

FIGURE 4. FORECAST OF U.S. ENERGY/GNP RATIO

Such changes in efficiency have come about as the result of improvements in production processes, changing prices, creation of sanctions and incentives, and, in some cases, substitutions of materials.

Finally, there are indeed changes in values taking place. Consumerism, environmentalism, and more frequently expressed questions about population growth are some more obvious examples. For decades, about half of a representative sample of people in the United States, questioned about the number of children which, in their view, constituted an ideal family, answered, "four or more." Now the fraction of people holding that view is considerably less than a quarter. Polling services that track values, such as Yankelovich's Monitor, have identified "forerunner" values groups in society holding nontraditional values: the forerunners, the new comformists, and the autonomous sectors. Among these groups is found beliefs in new, less materialistic ways to measure success, rejection of the orderly and rational in favor of the less planning and more spontaneous life, and the notion that simpler and small is beautiful.

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*T. J. Gordon, et al., A Technology Assessment of Geothermal Energy, Report 164-46-11 (Glastonbury, Conn., The Futures Group, September 1974).

Yet, the changes that are underway are small indeed in view of the magnitude of the problem. And they are not always what they seem to be. A person advocating a simpler life and less materialism, might still include his stereo and electric guitar in his lifestyle.

Some Technologies and Policies That Might Be Helpful

Scientific and technical developments will be urgently important in solving material problems. Technology could have an important role to play in providing substitutions, improving processing efficiencies, promoting recycling and reuse, developing economic processes for the use of lower grade ores, and in improving techniques of exploration and recovery.

In the area of exploration, clearly improved methods would be useful in helping to identify the location of mineral deposits, both in the United States and throughout the world. These techniques include, for example:

- Geological techniques, including field work, aerial surveys, subsurface investigations, mapping or rock types, and petrological studies.
- Aerial or orbital surveys using visible light, infrared, and microwave photography, as well as gravimetric and magnetic sensing.
- Geochemical exploration involving analyses performed on solid, liquid, and gaseous samples derived from surface manifestations and drilling cores.
- Geophysical techniques including measurements of temperatures, electrical conductivity, propagation velocity of elastic waves, and density and magnetic susceptibility of various strata.
- Seismographic techniques including active or passive seismic methods (active methods include reflective and refractive; passive techniques involve recording naturally generated microearthquakes or acoustic noise patterns within prescribed frequency ranges).
- Electrical methods including self-polarization, induced polarization, and telluric approaches.*

In addition to simply developing improved methods for identifying the location of resource deposits, general improvements in the field of geology would probably be very helpful. These improvements could lead to the development of statistical and mathematical methods for projecting the extent of the deposits, given certain surface and subsurface geologic information.†

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*T. J. Gordon, et al., A Technology Assessment of Geothermal Energy, Report 164-46-11 (Glastonbury, Conn., The Futures Group, September 1974).

†L. Heston and H. S. Becker, Focal Points in the Future of Food and Mineral Resources, Report 151-46-10 (Glastonbury, Conn., The Futures Group, July 1974). (Hereafter called Mineral Resources.)

The mineral position of the United States might also be improved through the development of new mining technologies. The industry in general is in a depressed state, as evidenced by the relatively slow advance of mining technology and the large number of imported technologies. The National Academy of Sciences recently recommended several potential research programs associated with improved mining technology. For example:

> "In conventional approaches there is a need to determine whether harder cutting materials can be synthesized in suitable sizes and shapes (tungsten carbide and synthetic diamond have led to considerable progress in this respect), and to explore their capabilities in factors affecting bit performance in various types of rock. Novel approaches for both soft and hard rock should be fully explored and evaluated for various mining conditions. These include the use of high powered lasers, electron beam, plasma torches, thermal fragmentation, ultrasonics and shock waves, percussion and hydraulic jet techniques, and automated continuous explosive systems."

> "It is recommended that research be accelerated on ways to automate mining operations. Such automation requires the development of suitable sensing devices (to monitor rock composition, for example), information processing equipment (minicomputers), and servo-mechanisms (robots), all of which have to be exceptionally rugged."*

Scientific and technological developments will also be important in the economic utilization of lower grade ores. The country will move from the use of its richest ores to those that are currently marginal. Therefore, a series of developments that improve the economics of the use of low grade ore will be necessary; these may involve for example, in situ leaching of ore deposits, improving methods of beneficiation (e.g., beneficiation of magnetic taconite in coarse crushing plants in the process of producing iron), lower cost transportation, new grinding and separation techniques, diminished energy requirements, etc.*

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*Mineral Resources.

Ocean mining is a particularly promising era. Here the processes involve both the removal of minerals from sea water through distillation or osmotic processes and the direct recovery of minerals from the ocean floor. Sea water contains almost all of the chemical elements, although only four elements--sodium, chlorine, magnesium, and bromine--are now being recovered in relatively large quantities. Landsberg, Fishman, and Fisher project that:

> It is not unreasonable to expect that within the next twenty to forty years some byproduct recovery will be carried out in sea water conversion plants built for meeting fresh water needs. But these plants will probably be of a limited number in the United States, at least in this century; barring the achievement of the extremely low-processing costs, application' will probably not be of major significance except for the sea water minerals already being recovered.†

With respect to use of the ocean bottom, mineral resources may be "mined" from beneath the surface of the Continental Shelf, recovered in the form of deposits from silt, slime, and solid debris covering the ocean floor (these materials are believed to have collected from land erosion and deterioration of submerged rock), and nodular material lying on the ocean bottom, at considerable depth. The recovery of nodules is particularly interesting since they appear to be primarily manganese and also contain nickel, copper, and cobalt. Nodules have been found at depths of from 500 to 3000 feet off the United States southeast coast, and to a range of 5000 to 14,000 feet in the eastern Pacific Ocean.

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*Mineral Facts and Problems, Bureau of Mines Bulletin 650, United States Department of the Interior (1970).

†H. H. Landsberg, L. L. Fishman, and J. L. Fisher, Resources in America's Future, 1963, p. 495. (Hereafter called Resources in America's Future.)

> ...one square mile would contain 70,000 tons of nodules or 20,000 to 35,000 tons of manganese...a breakthrough here would almost at once shake free the United States of growing dependence upon overseas sources. Recovery of phosphates from the ocean bottom, especially along the west coast, may exceed that of manganese.*

Recycling technology is indeed promising. Americans discard approximately 250 million tons of solid wastes per year. Today nearly all major materials are to some extent recycled. The rate varies from nearly 100 percent for lead to 50 percent for copper, 31 percent for iron and steel, and 19 percent for paper and board, to 4.2 percent for glass.† Considering just iron and steel, nonferrous metals, glass, textiles, and rubber, about 25 percent of the materials consumed in the country are currently recycled. Improved processes of recovery for the huge waste stream will reduce demand for virgin materials. The National Commission on Materials Policy has recommended that the government accelerate research and development and technology transfer on resource recovery from scrap, especially encouraging the recovery of resources in municipal waste.‡

Finally, science and technology can aid in the development of substitute materials for currently imported minerals or minerals that are likely to be in short supply in the future. Several of these substitutions are already in progress; for example, the use of plastics for metals in automobiles began in 1960 and had reached a level of about

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*Resources in America's Future, p. 496.

†"Report to Congress on Resource Recovery," Environmental Protection Agency (February 1973).

‡Needs in the Environment, Today and Tomorrow: Final Report of the National Commission on Materials Policy, p. 4d-19 (June 1973). Hereafter called Needs in the Environment.

10 percent by 1970.* The National Academy of Sciences recently urged that the search for substitute materials begin immediately:

> We cannot emphasize too strongly that the discovery and development of new and improved materials as possible substitutes for existing ones takes time, and that the process is generally driven by clearly perceived functional objectives rather than by ill-placed optimism that "something will turn up when the crunch comes."†

There are three major difficulties encountered in seeking to substitute one material for another: complexity of design considering specialized uses; accounting for the many uses of single materials of different combinations; and accommodating the huge volume of use of many commodities. In technically complex applications, such as nuclear reactors and jet engines, some substitute materials are nearly impossible to find. In other cases, the material is so crucial to adequate performance (e.g., palladium in telephone systems) that a substitute would mean redesign of the entire system if that were possible.

There are many political actions possible in this domain that relate to creating incentives or removing barriers to influence production or consumption of minerals. For example, taxes or subsidies could be created to promote conservation of scarce resources, federal stockpiling programs could be introduced, or materials rationed. As a single example, the Congressional Office of Technology Assessment recently pointed out that more than a hundred million acres of federal lands including wildlife refuges, national parks, and land administered by the Department of Defense are hardly used to produce materials, yet these lands are thought to be quite rich in mineral wealth. The various institutional factors that affect the use of such land include:

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*J. C. Fisher and R. H. Pry, "A Simple Substitution Model of Technological Change," Technological Forecasting and Social Change, Vol. III, No. 1, p. 75.

†Mineral Resources.

- Environmental policy, laws, and regulations.
- Mining and leasing laws and regulations.
- Administrative processes for environmental and other certification reviews.
- Economic policy (e.g., tax provisions such as depletion allowances and accelerated amortization of facilities or investment tax credit).
- Transportation policy (e.g., construction and operation of rail lines).
- Government programs for geological and geophysical surveying, exploration and mapping.
- Conflicting or concurrent federal-state jurisdictions (e.g., sovereignty and unitization of oil fields involving federal lands).*

The National Commission of Materials Policy recently recommended a full legislative program in this area. They urged that federal agencies intensify their efforts to encourage worldwide development of resources by all means, diplomatic, financial, and educational; that the federal government give users of materials economic incentives in the form of tax credits for expanded use of recycling materials; and that Congress modify the existing General Mining law to modify the procedure for reclaiming abandoned mining claims. They urged that prospectors should be granted sufficient rights to encourage their active exploration for new mineral deposits.†

Corporations that have the use of materials in short supply will be, I think, seen by the government and society as custodians entrusted with the job of changing those materials into products useful to the country. There will be penalties for performing this job badly and rewards for doing it well. Within a corporation that has under its control the use of materials in short supply, there will be new kinds of decisions about what to manufacture and produce. With input materials limited, it may not be possible to serve all markets and produce all products; what should be given priority? If business has no means for deciding, government will.

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*Request for Proposal from the Office of Technology Assessment: OTA/RP 75-4 (February 1975).

†Needs in the Environment.

Summary

In preparing the agenda for this symposium, EPA posed several questions. In this section, based on the foregoing discussion, summary answers to these questions are presented.

(1) What future resource issues do you anticipate will have major implications for EPA policy?

- Determination of more precise relationships between consumption of minerals and GNP.
- Public attitudes and expectation about what constitutes a "good life."
- World competition for minerals, availability and price.
- Extent of domestic proven reserves, their locations, and the willingness of the owners (including the federal government) and local and state governments to permit their extraction.
- The availability and cost of substitutes.

(2) How will various changes in human carrying capacities affect these issues?

- GNP growth and the material things it brings will continue to be sought by individuals and the nation as a whole.

- Shortages and high prices of materials will bring pressure to develop indigenous resources and more advanced technologies of waste processing, recycling, exploration, substitutes, and improved production and processing efficiency.

(3) What emerging environmental policy alternatives will need to be examined in light of these issues?

- Current policies should be reviewed to determine that they encourage the development of needed technology and are not inconsistent with the effective and appropriate development and use of indigenous resources.
- Policies will be needed to improve planning associated with projecting the future demand for minerals.

(4) What political and social constraints may limit the effects of EPA policy decisions?

- Suppose materials are short, prices high, supply uncertain, and unemployment pervasive. EPA policy decisions which are seen (correctly or incorrectly) to inhibit the effective development of indigenous supplies will be strenuously questioned. In other words, in this scenario, a backlash is indeed plausible.

(5) In view of future issues, what kinds of research related to resource use should EPA be undertaking now?

- Supporting the development of more effective exploration techniques, and geology in general.
- Participating in the evolution of new mining technologies.
- Pursuing the techniques for employing lower grade ores and beneficiation.
- Investigating the utility of ocean mining.
- Reaching an understanding and creating incentives for greatly intensifying recycling and waste processing technologies.
- Understanding a priori, the dynamics and potential for the use of substitutes for materials likely to be in short supply.
- Developing more effective economic and planning tools which help project the primary and secondary consequences of policy.

RESOURCES, INDUSTRY, AND THE ENVIRONMENT

Maurice R. Eastin
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RESOURCES, INDUSTRY, AND THE ENVIRONMENT

Maurice R. Eastin

EPA's charter from Congress is to set health standards and to enforce such standards. If we in EPA were to look at this charter without relation to the total environment, we could be accused properly of tunnel vision. If on the other hand we were completely broad in our interpretation we would give into other forces and our charter would suffer. Russell Train is consciously trying to operate reasonably within these bounds with one eye on health and the other on our economy. This is the decision of a reasonable and prudent man.

Our government is a system as well. What OSHA, Agriculture, Energy, Transportation, Interior, EPA do is all interdependent. At times, however, we give the impression that each segment of government is afflicted with tunnel vision or that government is a series of tunnels with no view from the mountain top.

If every agency takes its pound of flesh, the body politic will die. Administrators must decide whether they will be technicians or statesmen, picayune or wise, capricious or profound. Government also has an alarming proclivity for going from suspicion to conclusion with quite careless attention to the burden of proof. This is in many cases generated by an overdeveloped sense of self-righteousness and turns into unresponsive and arrogant government.

The dictionary is one of our great educational tools. It is also good for the soul now and then. The other day I decided to refer to it for some basic guidance. Health standards, as you know, are created to guide us all in environmental reconstruction. We can argue about them

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quantitatively, but I believe we all accept their objective. By definition health is: "The general condition of the body." We assume, of course, that this includes the brain or mind and that the objective is good health. Thus, the definition helps to point out the obvious--that health is dependent on the condition of the total body, considered as a system.

Now what about the definition of environment. Webster says it is "the aggregate of the social and cultural" conditions that influence the life of an individual or community. The word aggregate stood out and I looked that up: aggregate is a mass or body of units or parts somewhat loosely assocated with one another. The term associated led me to the definition of system: "a regularly interacting or interdependent group of units or forces forming a unified whole and tending to be in equilibrium."

Combining these definitions, we come to the conclusion that the environment is the aggregate of the interdependent interacting physical, cultural, economic, and social conditions, generally in equilibrium and that influence the life of the individual or community.

That is quite an impressive mouthful indeed.

The physical system within the total environmental system includes the air, water and land. It therefore follows that in dealing with water you are disturbing this interrelated air and land and you are at the same time disturbing cultural, economic, social factors which before such action were loosely in equilibrium.

Man however at the present time does not completely understand the total life or environmental system. To solve or to make progress towards the understanding of such a complex subject, our teachers have always told us to seek out a portion of the system, work with it, understand it, and use it as a building block to progressively reach our goal.

The Guiding Philosophy for the Future

I am convinced that the building block that we should use as a key to total understanding is the process--a subsystem of the total mystery--but a building block we understand nevertheless. If we look towards a more efficient process from the viewpoint of resources, economics, and energy, the environment will gain.

It is therefore a point of view we seek; a more technologically and system-oriented posture than the narrow view of pollutants coming out the end of a pipe. These are only indicators of the performance of the total system we seek to correct. And we are seeking progress not perfection. We cannot live with the economics of the end-of-the pipe point of view.

Application of Philosophy to Program Administration

But what can EPA do administratively to face up to the system concept and lead Congress into eventually using the system concept in drafting laws. I reemphasize that we at EPA must interface administratively water, air, and earth laws and second, effectively and efficiently absorb and understand industry technology and the processess--the building of the organization to do the job. The equally important manning of that organization and the quality of management will be left to another time.

At present, the whole energy is law oriented. I hold that this is the proper organization for the enforcement sections of EPA--and EPA is an enforcement agency; but I believe most deeply that this law orientation is in error for the program areas of EPA. We are now requiring municipal officials, agriculture and industry--the people we all must depend upon to get the job done--to mill about from pillar to post to seek out the receiving areas for technology and to be whip-sawed from water to air to earth to obtain incomplete nonsystem oriented decisions.

If we do not arrive at a system decision within our agency, how can industry plan and execute programs in the best interest of all our citizens? At the best, it is awkward and at the worst this loose administration is irresponsible.

But I do not believe this is happening because collectively EPA is bad or stupid or does not mean well. I am convinced that this is happening because our program area is not system-oriented. It is oriented and organized and fragmented--as is the rest of the agency--by air, water, and earth laws.

I believe the day will come when the agency will administratively put it all together in a system orientation by establishing basic process groups in the program areas. There are a dozen more or less basic processes or systems with which we must deal and, of course, many other less dominant systems. Those basic processes are: agriculture and food; paper and pulp; steel and iron including foundries; aluminum; copper and nonferrous metals; electric power; coal; petroleum and refining; chemical organic and inorganic; glass; automobiles (mobile sources); cement; plastics; synthetics; rubber; textiles; electroplating; public waste and resource recovery; and drinking water. These process groups, to which we are now going philosophically in EPA research, will deal with all facets of the process including energy, resources, economics, noise, air, water, and solid waste. They will also be the recipients of all technological data and should therefore understand the process and should assist the industry in improving the process rather than dealing negatively with more sewage disposal plants or removal equipment.

You have just had some heart surgery described to you because the program area is the heart of EPA and all the other sections should support it. This orientation already exists to some degree for municipal waste water and mobile sources but we stop there; we do not go on to industry and agriculture. To support these process groups through which all progress will flow will be such existing functions as: toxic substances; resource recovery; pesticides and agricultural chemicals; noise; water chemistry; fuels; research (applied only); hazardous materials (radiation); ocean disposal; monitoring; chemical and physical support; radiation; land use; economic studies; and air cleaning systems.

It's all there now in EPA but very importantly we have not put it all together, and you cannot find it. It is so fragmented we in EPA really don't know where it is either, but please keep that quiet. I would not want that to get around; it's embarrassing.

The only counter argument in EPA has been from EPA lawyers. They say this would allow industry and EPA to get too cozy. This is a typical and proper reaction to those embued with the arms length legal philosophy. The functional logic and simplicity of such a system organization should be its strength and its protection from hanky panky. But, importantly, this would improve our technological communication and understanding greatly.

When we do progress to a system orientation our decisions will be more sound and our understandings will be more profound--at that point, we will truly embark on positive environmental reconstruction rather than negative restrictive control.

Application of Philosophy to Research

How can this basic system philosophy be applied to research? I repeat that our society cannot afford the economics of end-of-the-pipe negative environmental control. I have just suggested a system approach to the Administration of Environmental Reconstruction.

Again in research I believe we must concentrate on the process, but I do not think EPA or any government agency should direct or execute such process research. I do not think government can duplicate the talent in industry nor should it even attempt to do so.

EPA's function is to augment and stimulate process improvement in cooperation with industry, not separate from industry. Industry on the other hand should direct and execute process research to create more energy-efficient, resource-efficient economically sound processes, and the environment will thereby be served. And the market will always flow to the most efficient process.

We should not direct our thinking to handling waste products. We should direct our thinking to byproducts and new products.

A microcosm of what I have in mind already exists on the Houston ship channel. As infamous as this area was in the past, it nevertheless illustrates that the effluents or emissions of one plant can become the feedstock for an adjacent process. This is the concept of the energy complex or the industrial complex. Without this concept even today our pollution problems and waste of resources would be greater. The extension and refinement of this concept in our processes will serve energy, make better use of our resources, and serve the environment--all within economic reason.

Application of Philosophy to Legislation

The EPA must lead the way in administration, in research, in the philosophic treatment of our environmental challenges--to show Congress that the system approach is the way to go in legislation. At the present time we have over-legislated too-detailed air and water laws, which do not relate to the earth or to each other. This creates a heavenly badminton game for bureaucracy, but industry and the public are taking a beating as the shuttlecock.

I would be so bold as to say the day will come when Congress combines our air, water and land legislation into a single more flexible system package either through amendments to the present laws or repeal and replacement of existing laws.

Summary

In summation, I have suggested my concept of what the future may bring in philosophy, administration, research and legislation. I may have done this with a seeming ingenuous optimism, but I have done so to stimulate our collective intellectual appetites with a bit of spice and to present to you my concept of a sound structure on which we can plan and execute basic and applied research.

RESEARCH NEEDS

FIRST VIEWPOINT

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AN AGENDA FOR RESEARCH

Lynton K. Caldwell
Indiana University

The primary need in effective research is to properly understand the problem about which knowledge is sought. Failure to satisfy this need has accounted substantially for the deficiencies of our environmental research in meeting the needs of public understanding and policy-development.

We have attacked specific problems of environmental protection without adequate reference to the general and basic causes of our environmental predicament. We have launched into research unprepared conceptually or institutionally to deal with the environmental problem in its true and full dimensions. In consequence, we have no basis for discovering what we need to know to bring our general environmental situation under control. We cannot be sure that in solving one problem we might not be inviting others equally unwelcome.

Our primary research task is therefore to construct a hierarchy of knowledge that would relate what we know to what we need to learn, and would help us better to understand the multiplex relationships comprising the total environment. This structure, which would never be finished, could afford a rational basis for identifying priorities and critical paths in our research efforts. It would provide a more reliable means than we have today for determining how most effectively to deploy our investments in environmental research.

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Identifying Research Needs: A Complex Task

The idea of a coherent structure or hierarchy of knowledge implies at least three types of research needs that require fulfillment in attacking both the lesser and larger problems of man's environmental relationships. Our particular focus is upon the environmental impacts of changing resource usages. But the needs are equally those of environmental research generally.

Three interrelating types of research needs may be identified. They are (1) substantive, (2) functional, and (3) conceptual. Substantive needs comprise the knowledge or understanding required to cope with environmental problems--in our purview, with the impact of changing resource usages. Functional needs refer to the skills, methods, and facilities required to obtain substantive knowledge and to bring it to public awareness in forms suitable for public response. Conceptual needs pertain to the comprehension and appreciation of the human environmental predicament, developing perspective on the total environmental research task and its complexly interrelated parts. Only to the extent that each of these needs is met can any of them be satisfied.

Substantive Needs. The knowledge aspect of research needs presents the following tasks:

The obvious first task is the identification of specific information, either absent or inadequately developed, concerning the environmental impact of human activities, including resource usages. The need is for answers to the question: What do we need to know concerning the environmental impact of resource usages that we cannot obtain from our information base as presently organized? This need for knowledge is often formulated as a checklist of researchable topics. A recent listing by the Environmental Studies Board of the National Research Council is appended herewith (Attachment A). The utility of such lists is limited.

They are analogous to shopping lists rather than to program budgets. They may help to identify environmental problems needing attention, but they provide no indication of interrelationships or of relative priorities for research. Moreover, the shopping list approach provides no means for discovering what pieces of information, if any, may have been overlooked.

The second task of meeting substantive research needs is therefore the structuring of researchable topics into a hierarchy of knowledge which is also a grand design or map for research effort. The difficulty of this task will be apparent to anyone familiar with the field of environmental research. But if successfully accomplished, the rewards would be commensurate with the effort. The form required for such a structure may not be determinable a priori. A three or four dimensional, rather than graphic, model might be required. But, however constructed, it should reveal linkages, dependencies, and discontinuities in our knowledge of the environmental impact of resource usages.

Because the time dimension must be reflected in any model describing change, no hierarchy of environmental knowledge can be made final. Were it to be finalized, it would rapidly become invalid, failing to reflect the reality of the world in which change is the normal state. Among the dynamics to be accounted for are changing physical circumstances, for example, in human populations; in the economy; in resource availability; and in technology among others. In addition, new knowledge alters the configuration of the previous state of knowledge; public attitudes and political circumstances also change, with feedback affecting still other factors. A valid configuration is therefore necessarily dynamic.

Yet for the particular point in time at which environmental impacts are being examined, it should be possible to determine relative priorities among specific research needs. And so a structuring of knowledge provide criteria for priorities. However formulated, these criteria should reflect: (1) urgencies, as estimated by the imminence, magnitude, intensity, and duration of the impacts; (2) feasibilities, as determined by adequacy of existing information, technique, and social acceptability; and (3) dependencies among interrelating environmental factors. From these data, projected within a time dimension, it should also be possible to discern the "critical path" that research must take to solve an environmental problem by a specified future time.

Functional Needs. Considerations of the substantive needs of environmental research are incomplete until the means to meet these needs have also been considered. Three interrelating aspects of functional need may be identified: research capabilities, institutional arrangements, and funding.

Capabilities include personal and professional skills, methods, and technology required to identify and solve environmental problems. These capabilities must necessarily match the complex variety of environmental relationships. This is to say that they must be multidisciplinary, and yet coherently related through orientation toward common or compatible research goals--and must be sustainable over time.

These requirements imply need for an institutional infrastructure designed to help maintain focus, orientation, and personnel capabilities. Built into these arrangements should be mechanisms for error-detection and correction, to control quality of output, along with periodic assessment of the course of the research effort and the adequacy of the research product in relation to the needs of society and of a more effective research design.

There is an obvious need for funding sufficient to sustain the professional, technological, and institutional capabilities required for performance of the research tasks. It is less apparent, but equally necessary, that the funding commitment be adequate in form and duration as well as in amount. It is largely on the critical and controversial issue of institutional support that efforts to respond to this comprehensive interpretation of research needs have been, and may continue to be, rejected.

Conceptual Needs. The third and most basic research need is for seeing the environmental predicament of modern man in its full dimensions. Meeting this need implies discovery of the nature of these dimensions, a task not yet fully accomplished. It is neither necessary nor possible here to describe the circumstances comprising the environmental difficulties of modern man. But a list of writings that attempt to do so is appended (Attachment B).

To the extent that the conceptual need is adequately answered, it satisfies three requisites of environmental research. First, it assists the framing of a set of general organizing propositions that enables the researcher to assemble discrete facts into a coherent operational structure of information. Second, the conceptual approach affords a rationale for the potentially greater efficiency of fundamental research as against the lesser efficiency of short-term expedient problem-solving. Third, it reinforces tolerance for the risks associated with creative inquiry as against the common tendency to insist upon quick, specific, and politically acceptable results.

In the practical tasks of environmental research, these three aspects--substantive, functional, and conceptual--are inseparable. Construction of a hierarchy of knowledge would be a conceptual task, applying functional means to the organizing and extending of substantive knowledge through facilitating institutional arrangements. As this process continues, the concepts change with the advancement of knowledge, and even a substantially stable configuration of knowledge will not be the same from year to year.

Analyzing and Evaluating Substantive Research Needs

The major impact of human society upon the environmental follows from its resource usages. A large part of environmental research is therefore concerned with how the adverse aspects of this impact can be alleviated. Its foci are primarily on environmentally conserving management of resources (for example, the regulation of strip mining), and on changes in consumption that reduce total resource demand or preferentially utilize resources that entail minimal environmental disruption (for example, sun and wind). A large body of research pertinent to environmental policy is therefore concerned with resources and their uses. Hence, an important research need is to understand how our knowledge of materials and resources can be articulated into the general structure of environmental knowledge.

This task requires an understanding of the semantics of the resource concept. Contrary to the implications of popular usage, resources are not per se physical materials or their properties. "Resource" is a techno-economic concept, and materials become resources only when they are discovered to have a practical utility. Materials that are truly inaccessible, or for which no use is known, are not resources in any practical sense. No definition of a resource is adequate that, at least by implication, does not indicate the usages of the resource and the technologies through which these usages are actualized. A very large part of the apparatus of modern industrial society (or indeed of any human society) consists of resource technologies that implement, among a wide range of functions, those of: (1) discovering, (2) extracting, (3) transporting, (4) processing, (5) fabricating, and (6) reclaiming or recycling.

These technical processes imply a cultural and especially an economic infrastructure through which society "selects" what resources are sought; how, when, in what quantities, and at what cost to the environment.

Consumption patterns are built into this socioeconomic infrastructure, and environmental research concerned with how resources are used is inevitably confronted with relevant questions concerning popular values, preferences, and lifestyles.

Even a superficial probing of the consumption aspect of resource uses clarifies the preference of politicians and public officials for dealing with resource-environment problems in their supply rather than in their consumption phases. The history of both energy and environmental pollution policy illustrates the understandable tendency of government to try to accommodate existing consumption patterns rather than to propose radical alterations in the infrastructure of the economy that would significantly change resource usages. For example, in coping with the impact of the automobile on resources and the environment, political choice has opted for temporizing alternatives such as emission controls, improved combustion efficiency, lower speed limits, and car pools, as contrasted to more fundamental measures such as pollution-free fuels, electrified rapid transit, drastic controls over land development, industrial location, and the design and construction of urban facilities. The reason for the choice should be apparent. In "making the present system work better," the politically dangerous value question is contained; in seeking a better system, a Pandora's box of alternative values is opened.

Because resource uses are built into a complex and relatively stable techno-economic infrastructure, changes in usage seldom occur abruptly. A decade is perhaps the shortest span of time in which to ascertain or to effect significant changes. Studies in the implementation of scientific and technical innovation make doubtful the wisdom of limiting research on the environmental impact of changes in resource usage to intervals of less than a decade. How far into the future research can, or should, be projected is perhaps best determined pragmatically. Different phenomena may proceed on different timetables. Gross and long-range tendencies are often easier to verify than are short-range changes, subject to transitory variables of lifestyle, fashion, political interference, and even fluctuations of the weather. Technological change takes longer. It is difficult to name any major environment-affecting technology (for example, pesticides, fission reactors, or jet propulsion) that have not required at least a decade to develop to the point of significant environmental impact.

Because resource uses are technologically implemented, it is hardly profitable to consider whether environmental research should focus on the uses of resources or upon their associated technologies. Both must ultimately be considered although specific aspects of a total resource use may be sectored out for study, provided its total context is kept in mind.

Insofar as efforts are made to prevent undesired environmental impacts from changes in resource usages, the following knowledge is needed. Basic information concerns the characteristics of the resource in question: (for example, the properties of the various types of coal). These data, joined to information regarding the available implementing technologies, provides factual data for determining the amenability of the particular resource usage to environment-protection management, at what costs, and upon what conditions? If the incidents of its environmental impact, its degree of hazard, and alternative methods and costs of prevention or amelioration can be ascertained, the substantive knowledge is at hand upon which policy decisions can be based.

This knowledge, to be adequate to policy needs, must provide answers to the following questions. First, how complete and reliable is the evidence regarding environmental impacts? Second, from what phases of the resource-use cycle are these impacts incurred? Third, to what extent are these impacts: (1) unavoidable if the resource is used at all; (2) avoidable through alternative approaches to the purpose to be served (for example, through alternative technologies or resource-use strategies such as cutting down usage to below the threshold of adverse effects); and (3) reversible or correctable by physical, technical, economic, and political criteria. Fourth, what are the second- and third-order consequences of initial impacts, including synergistic effects, sequential chain reactions, and the time-space ramifications of these phenomena.

A fifth question, which must be answered for responsible public officials is: What are the true and full costs, including the environmental costs, of meeting a perceived social need through a particular resource usages? What alternative tradeoffs exist among resource usages, and against what criteria are competing values to be identified and weighted? This cost assessment, if complete, will include estimated opportunity costs of alternative resource uses and strategies. And this calculus of opportunities need not rest solely on ethical justification, but equally upon the practical consideration that future possibilities may materialize much sooner than expected. The international embargo and cartelization of oil is a dramatic example of the costs that may be incurred by optimistically discounting future possibilities.

Requisites of an Adequate Agenda for Research

The thesis of this paper has been that the nature of modern man's present environmental circumstance sets the conditions, and hence the requirements, of research that can answer to our policy needs. More than a shopping list of researchable topics is required to construct a meaningful agenda for research. An agenda that fully corresponds to our environmental predicament must somehow attempt to account for all of the significant factors of that predicament. The outcome of this effort would be a structure or hierarchy of environmental knowledge that would be larger than the operational agenda of any agency, but which could provide orientation and perspective for the research missions of organizations such as the EPA.

No attempt is made in this paper to outline such a structuring of knowledge. That function is a primary research task, and it is not necessary to know precisely how to do it to understand that it needs to be done. Nor does the probably correct belief that this comprehensive approach will not be taken argue against its validity. Mankind has always been the maker of most of its troubles, and only in extreme duress has it faced its options realistically in preference to acting upon politically or psychologically convenient interpretations of reality. Hence, there is no compelling reason to believe that in America, or elsewhere, it will effectively seek the kind of knowledge needed for coping with its environmental problems.

We may expect that society will continue to seek convenient knowledge, ostensibly of direct and immediate practicality. So far as this knowledge goes, it may be reliable, but there are dangers in assuming that this pragmatic approach to our research needs will enable us to discover them fully or adequately. Two hazards of defining research needs either in response to ad hoc exigencies or by means of extemporaneous checklists, are that these approaches not only provide no means of ensuring against omission of significant variables from consideration, but may actually lead toward erraneous conclusions. No structuring of environmental knowledge is adequate that does not identify the linkages, cybernetic mechanisms, and discontinuities in the structure. Unless all significant parameters of the environmental research task have been recognized, it will be impossible to identify the critical path leading from mere factual data to coherent policy alternatives.

If the foregoing thesis is valid, it then follows that in the construction of a hierarchy of knowledge, problem analysis and definition require major attention. This is especially so because research toward environmental problem-solving must proceed even while a more adequate configuration of knowledge is being created. Our environmental exigencies may not wait until our knowledge is adequate to cope with them. When there is a necessity to act, action must be taken even if on insufficient knowledge. But the objective of a comprehensive structuring of knowledge is to minimize such necessities. Thus research toward more adequate conceptualization of environment-resource problems is as important and practical, and may be less costly, than practical research directed toward solving specific problems out of context.

Practical ad hoc research may be applied (perhaps wastefully) toward solving the "wrong" problems. For example, research in automobile-emission controls may retrospectively appear to have been a poor investment, considering the eventual and relatively early need for alternatives to petroleum-powered propulsion. Moreover, research inadequately conceptualized may lead to solutions that create new problems in addition to those that it presumes to solve. Pesticide research has frequently led to such unwanted consequences. And finally, problem-solving research projected on narrow conceptual or technical grounds may completely overlook simpler and less costly solutions to a problem that would become apparent only through a broader surveillance of the field of relevant knowledge.

Any survey of the state of the field will show that our environmental research needs have largely been defined by ad hoc and shopping-list approaches. And it is probable that regardless of their inadequacies, these will continue to be the guiding approaches. They are consistent with the institutional and political realities that produced them, whereas the comprehensive structuring of knowledge approach is not.

Social and Political Constraints on Environmental Research

Our institutionalized arrangements for environmental research--academic, industrial, and governmental--hopefully produce at least what they are capable of producing. It is hardly surprising that they seldom produce more than they were designed and funded to produce. The functional needs of a comprehensive structuring of environmental knowledge--capabilities, institutional infrastructure, and funding--remain at present largely unprovided. Nor are they likely to be provided until the need for a more adequate concept of our environmental problems is recognized by the American people and their political representatives.

The prospect for an affirmative public response to this comprehensive interpretation of research needs is not promising. Constraints against adoption of this broad and long-range perspective appear firmly grounded in the psychological and cultural assumptions prevailing in (but certainly not unique to) American society. These assumptions are seldom made explicit. They are instead deducible from behavior, and they indicate tendencies and biases in the following pertinent respects:

- Insistence on quick and direct answers regardless of the complexity of a problem (a penchant for "low-budget spectaculars").
- Optimistic assessment of natural tendencies (matters to turn out better than we expect).
- Specialization and reductionist approaches to problem-solving (more appropriate to physical than to environmental problems).
- Temporizing compromise as against lasting but conflict-producing solutions (no one gets hurt by avoiding trouble).
- Preference for symbolic responses over actual remedies that would disturb the sociopolitical system (note the tendencies of public programs pertaining to health, poverty, crime, and environmental pollution).

But perhaps the greatest constraint on environmental research today is the strong tendency of governmental and foundation executives to avoid or to minimize risk. These officials and their institutions are poorly equipped for risk assessment in relation to the prospective rewards of obtaining reliable knowledge of future environmental hazards. Avoidance of future substantive risks through acceptance of present deprivations and controls has little political appeal--especially when the future hazard is not demonstrably certain and is in any case relatively remote. It is a near axiom of political life that officials are more readily punished for mistakes than for inaction. Better to avoid personal risk now than to incur public or official displeasure for attempting to forestall social risks in the future.

The risk-avoidance that tends to characterize official behavior is also found among researchers. They tend to select projects for which funds are available, which promise earlier rather than later or uncertain payoff, which can be made consistent with specialized disciplinary orientations, and which minimize dependence on other researchers. Comprehensive approaches to environmental problem-solving imply multidisciplinary inputs and coordinative, collaborative team work to a degree that may obscure the identity (and thus the distinction) of the individual researcher. But research as presently instutionalized tends to reward individuals, not groups. Individuals receive promotions--not research teams.

The risk in opting for the development of a comprehensive structure of environmental knowledge is the risk of sponsoring efforts that are novel, that require changes in values and assumptions, that cannot promise early or clearly defined returns. Even though a research effort of the kind here indicated would absorb only a small part of the money spent on environmental research, and would reinforce rather than compete with productive work in progress, few are the public officials that may be expected to recommend it and few are the legislators that would respond favorably to a proposition so heavy on theory and so light on politically usable results.

It therefore follows that the investment needed to meet the primary environmental research needs of the nation will not be made. It does not further follow that environmental knowledge will not be advanced. Useful and important work will be done. But in the long run more money will have been spent, less useful knowledge will have been acquired, and fewer environmental and resource policy errors avoided than would be probable had more support been given to the more fundamental and continuing need for an adequate structure of environmental knowledge. Nevertheless the case for a better approach should be presented, even though the probabilities of its early acceptance are slight.

Attachment A

CRITICAL ISSUES IN NATURAL RESOURCES

Agriculture

World Food - U.S. production, technology transfer to foreign nations

Renewable Resources - as substitutes for nonrenewable

Fertilizer - production from other sources than natural gas
biological fixation of N_2

Runoff pollution by chemicals and fertilizer

Food losses

Air Pollution

Health basis for standards, epidemiology

Automotive emissions, energy relationship

Sulfur oxides and sulfates problems

Acid rain

Atmospheric chemistry and transport

Ozone layer

Atomic Energy

Breeder reactor

Nuclear risks

Role of nuclear in energy mix

Uranium reserves

Radioactive waste disposal

Chemicals in the Environment

Asbestos

Chlorofluorocarbons

- Pesticides
- Toxic substances regulation
- Biogeochemical cycles

Coal

- Increased mining
- Strip mining, rehabilitation
- Slurry pipelines
- Coal conversion processes

Coastal Zone

- OCS resources
- On-shore impacts
- Estuaries

Ecology and Ecosystem Analysis

- Fragile ecosystems
- Managed ecosystems
- Ecology as a predictive science

Electric Power

- Fuel sources
- Thermal pollution

Energy

- Better numbers on world oil and gas reserves
- Demand modification and conservation - what is possible and how much does it help
- Coal conversion problems
- Increased coal production
- Hot rock geothermal

EPA - $5 Million Program

Decision-making with uncertainty

Comprehensive environmental management, cross-media pollution considerations

ORD effectivenesss

Fish and Wildlife

Predator control - evaluation of alternative strategies

International

SCOPE - ICSU projects

UNEP liaison

Bilateral projects

Environmental protection requirements as a part of AID

Institutional Problems

Environmental Impact Statement quality and effectiveness

The need for an Environmental Analysis Institute

Obtaining and using proprietary information in public policy deliberations

Land Use

Scientific basis for land use planning

Local versus federal control issue

Carrying capacity concept

Land quality protection equivalent to AQ and WQ

Patterns of settlement

Marine Affairs

Fisheries management

Mineral resources recovery

Ocean as a sink, dumping, rivers, out falls, etc.

Marine mammal protection

Deep water ports

Minerals

Forecasting reserves, demand, and possible shortages

Dependence on foreign sources

Mobilization of minor elements

Motor Vehicles

Emissions to ambient relationship

Unregulated emission species

Pollution control versus energy requirement

Oil and Gas

Oil spills

LNG transport

Pesticides

Comprehensive decision making

Eradication

Integrated pest management

R&D

EPA - Office of Research and Development

Interagency coordination

Solid Waste

Containers

Recycling

Incineration

Tailings

Water Pollution

- NCWQ report
- Effluent change concept
- Dredging
- Trace organics
- Water reuse
- Nonpoint sources

Weather and Climate

- Weather modification
- Climate and agriculture
- Ozone layer.

Attachment B

REFERENCES ON ENVIRONMENTAL DIFFICULTIES

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REVIEW OF THE PAPER BY L. K. CALDWELL

Stanley A. Cain
University of California, Santa Cruz

Professor Caldwell has told us at the start that environmental research has fallen short. He is blunt about it. Having failed to understand the problem about which knowledge is sought, we have launched into isolated studies without being aware of the true and full dimensions of our environmental dilemmas. However clever technologically, we have been unprepared conceptually and institutionally to deal with environmental problems and bring them under control. I accept his indictment as being generally true.

In comparison with the life sciences, the physical sciences and their derived technologies have an enviable exactness. The life sciences lack this except when they can use the knowledge and methods of the physical sciences. By then we are not dealing with life but with the substratum through which life phenomena are manifested. In either case, Caldwell says that we cannot be sure that in getting data on one problem we might not be inviting others equally unwelcome in terms of environmental quality.

There is no hint from him that we should wish any less support for the natural sciences. It is, rather, that our not fully understanding the problems about which knowledge is sought, the branches of science are not coordinated, especially in relation to the wider understandings, institutions, and methodologies of the social sciences. Political science, economics, and sociology are an embarrassment. People do not behave like physical particles and reactions; they are unpredictable and seem to do as they please.

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In the first paragraph he stresses the deficiencies of environmental research in meeting the needs of public understanding and policy development. He does not charge that the natural sciences are more at fault than the social sciences in producing environmental dilemmas. Lacking a holistic philosophy, we have been unable to anticipate the problems that are produced by partial solutions which, often, do not in fact solve an environmental problem or, in doing so, produce others. He states his thesis in these words: Our primary task is to construct a hierarchy of knowledge that would relate what we know to what we need to learn, and would help us better to understand the multiplex relationships comprising the total environment.

I like Caldwell's philosophy and his wisdom so much that I would be happier had he not used the word "hierarchy" which indicates a linear order of authority as from pope to parish priest or from king to commoner. However, it turns out that he means that only multidimensional models will serve well for thinking about and working on environmental problems. He certainly does not mean that we should establish a linear list of things to do but, rather, that we contemplate all kinds of knowledge that we need if we are to escape from our environmental predicaments and stop producing nonsolutions. A nonsolution, of course, consists of learning about a thing, condition, or process and then putting the results into practice with scarcely a thought for the consequences. When a problem is isolated to be attacked we cannot afford any longer to think of it as existing in isolation. Its isolation is of our creation, for the purpose of studying one variable at a time. The condition or process, whatever it may be, will most likely have a family of causes and any changes that result from research will likely have a complex of consequences. The environment cannot be dealt with satisfactorily by linear thinking--an improvement over compartmentalized thinking--nor can it be usefully understood out of context.

Being a political scientist, and a broadly based and wise one at that, [illegible] immediately emphasizes in his paper the principal deficiency in environmental research, the failure to relate the environmental efforts of scientists and technologists to the needs of public understanding and policy development. The problems arising from the progressive loss of environmental quality cannot be solved by the sciences alone, nor by the familiar engineering technologies that apply them, however clever they may be, but require the full panoply of the social sciences. I would add my belief that solutions of environmental problems also require participation of the humanities, the communication fields, and a dedication of our institutions of education at all levels.

Caldwell organizes his thoughts. For example, he says that research needs fall into three interrelated categories. First are substantive needs for knowledge to cope with a problem. Second are the functional needs for skills, methods, institutional arrangements and facilities, and funding. Third are the conceptual needs to see environmental problems whole, not failing to comprehend that a thing, condition, or process is likely a mere link in a complex situation. These three sets of research needs have to be met if the objective of anticipating environmental consequences of our actions are to be anticipated, especially as changing uses of resources arise.

The record is not one to make us sanguine about the future. We have not anticipated the environmental consequences of our actions, and we will do better in the future as resource usages change only if research is organized so as to deal with all of the cells and linkages of the complex systems rather than with things, conditions, and processes one at a time. The encouraging point is this: the core of the wisdom that has called forth this conference.

Caldwell also recognizes that no such framework for the guidance of research is a template of enduring usefulness. It is a device for keeping us humble and reminding us that change is inevitable. As he says, new knowledge alters the configuration of the previous state of knowledge. There will be no simplistic and final solutions. This position is not defeatist. On the contrary, it is the only position that promises some confidence that life and environment can be satisfactory.

He distinguishes between natural resources in being and those that are latent or potential. He says also that it is of little use to list known resources in order of importance except, perhaps, as to known and demonstrated uses at the present. This causes him to conclude that it is profitless to do research only on existing resource-use patterns. This would be little more than fine-tuning the wrong engine. He expresses the point more elegantly when he says "the tendency of government is to try to accommodate consumption patterns rather than to propose radical alteration in the infrastructure of the economy that would significantly change resource usages."

For a variety of reasons, the techno-economic infrastructure is not geared for rapid change. It is too complicated to do so. For every resource there exists a sequence of steps between the raw material, condition, or natural process in nature and its practical usage. Every link in a sequence and every chain that ends in a different usage has its technological requirements, capital requirements, skilled personnel, markets and merchandizing system, and profit for some. Each step may have its own environmental impacts and there is no overall responsibility for the system. There has been no mechanism for pinpointing the sources and causes of undesirable environmental consequences, and hence no centralized responsibility until recently a start has been made at the federal level with the EPA.

It is not unfair, I think, nor unappreciative to say that success awaits a parallel responsibility in all pertinent governmental agencies and all private organizations with involvement. As Caldwell says, environmental impacts occur at every step, not just with the disposal of the ultimate waste products. This being true, policy requires reliable and specific information concerning impacts at every stage. Which impacts are unavoidable, granted the nature of the resource and the technology of extracting it from nature? Which impacts can be ameliorated or removed with a different technology? Similar questions can be asked at each step. Which impacts set off a chain of impacts? What is the duration of the impact? How wide is the area affected? What are the true and full costs? Who shall bear the costs? How shall those who suffer get redress?

I do not find Caldwell sanguine about the outcome even though there is a growing awareness of the loss of environmental quality. He says that mankind has always been the maker of most of its troubles, and only in extreme duress has it faced its options realistically in preference to acting upon politically or psychologically convenient interpretations of reality. Hence there is no compelling reason to believe that in America, or elsewhere, it will effectively seek the kind of knowledge needed for coping with its environmental problems.

There are several reasons for this pessimism. We continue to seek convenient knowledge of direct and immediate practicality. This approach provides no means of ensuring against leaving out significant variables. I would impose an interpretation of my own at this point by ascribing the prevailing attitude to a general lack of understanding of the intricate interconnectedness of life and environment. We find more holism in a good mystery novel than in the usual textbook. The further along one moves in the educational system, the more compartmentalized information gets. The tendency is to atomize information rather than to synthesize it except in specialized fields of learning. On the other hand, religion and philosphy tend not to deal with the same facts in an objective way that confront the scientist, the technolgist, the economist, the politician, and all the rest who run our world for six days a week at least. It is easy enough to blame someone for an undesirable environmental impact. When the causes are shared by everyone, when the system is at fault, the victims are the culprits.

Quite properly, Caldwell calls for a structuring of knowledge that will show the linkages and the feedbacks and loops. We need to try to see our problems whole. We are not used to this and it is easier to blame the government: administrators, politicians, or both, forgetting that we are the government when we make use of our citizenship. It is easier to blame industry, bankers, lawyers, merchants, labor, farmers, or for that matter the Arabs, the Russians, and the people downtown or in the suburbs. There is enough blame to go around. Scientists and engineers get some of it, and the economists, political scientists, sociologists, psychologists, and the planners, too, although they are more of an enigma.

This situation is uncomfortable but not all that bad because the people are grasping collectively, if not as individuals, that our lives are interrelated even though we are not organized to deal with the interrelations. Caldwell has said or implied this, although more elegantly than I have, in his insistence that we have to learn to think and act in relation to the system with all of its frustrating linkages, cybernetic mechanisms, and discontinuities.

I do not find Professor Caldwell optimistic. In his paper I find such statements as these:

- The prospect for an affirmative public response to this comprehensive interpretation of research needs is not promising.
- Perhaps the greatest constraint on environmental research today is the strong tendency of governmental and foundation executives to avoid or minimize risk.
- The risk-avoidance that tends to characterize official behavior is also found among researchers.
- The investment needed to meet the primary environmental research needs of the nation will not be made.
- Mankind has always been the maker of most of its troubles, and only in extreme duress has it faced its options reaslistically in preference to acting upon politically or psychologically convenient interpretations of reality. Hence there is no compelling reason to believe that in America, or elsewhere, it will effectively seek the kind of knowledge needed for coping with its environmental problems.

An old Irish saying is that we are going to hell in a wheelbarrow. Today the figure of speech might be anyone of a number of vehicles that travel at supersonic speeds.

I think that Professor Caldwell is somewhat carried away by his theme. But he is at this conference telling it like it is, a conference sponsored by a federal agency with a host that is famous for its share of atomized research.

The holistic science of ecology is well and working. Earth Week was not a fiasco for innumerable young persons. Resources for the Future is staffed by economists who are alert to and concerned about environmental problems and rewriting a good deal of economics. There are physicists and chemists doing homely but valuable work adapting waste disposal systems, energy-capture, and water-conserving devices to the small landowner and his home. Even some agricultural experiment stations are showing tolerance for organic farming and a growing unease about pesticides and inorganic fertilizers. Those who weep for wildlife arrived instinctively where the genepool geneticists are now coming.

The young people who have opted out are returning to colleges and universities and will help when they see that there is a chance for sensible changes in resource usage and environmental protection. Many are studying natural history, ecology, the earth sciences, and land-use planning, looking to careers in resources management. This conference will be appreciated by them and many others.

RESEARCH NEEDS

SECOND VIEWPOINT

THE DESIRABILITY OF AN INTERDISCIPLINARY APPROACH TO RESEARCH ON THE ANTICIPATION OF ENVIRONMENTAL IMPACTS OF CHANGES IN RESOURCE USAGE

Robert C. North
Stanford University

The Compartmentalization of Knowledge

Until recently, a major constraint affecting environmental research and policy-making has emerged from the fact that human knowledge has tended to be compartmentalized among many distinct disciplines--physics, chemistry, geology, engineering, biology, economics, psychology, management, political science, law, and so forth--whereas reality involves the intense interaction of variables that cut across these and other disciplines. Especially in the social sciences, each discipline has been inclined to approach the study of environmental problems in terms of its own partial view, specialized conceptual framework, vocabulary, data, and method of analysis. As a consequence, many experts tend to wear professional blinders, and policymaking agencies--to say nothing of the general public--are bombarded with unrelated or conflicting viewpoints which often confuse, rather than elucidate, the basic issues.

Resource usage and consequent environmental impacts are functions of the activities of human beings organized, on various societal levels, into complex social systems. Without human beings and their social systems no such usages and impacts would take place. It is almost axiomatic, therefore, that problems of resource usage and environmental impacts are virtually inseparable from the structure and functioning of social systems ranging from the community and private firm to the nation and even the world.

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Because of intense interactivity among critical variables and because of complex social, economic, and political--as well as technological--feedback arrangements, we are dealing with a congeries of problems that are extremely difficult for analyst and policymaker alike to manage successfully or even properly understand. To ancipate the environmental impacts of changing resource usage over any sustained period of time, it is necessary at the very minimum: (1) to obtain some notion of the effects of such impacts upon the social systems that produce them and (2) even beyond that, to identify at least some of the consequences for subsequent usage change of any social, economic, or political alterations that take place as a consequence of previous usage change (as well as usage change resulting from other factors).

The Importance of Population-Resource-Technology Variables

Of the many variables that seem pertinent to an understanding of environmental problems, there are three--population, resources, and technology--that are intensely interactive and at the same time fundamental to enlightened domestic and foreign policy.* Obviously, a considerable number of other important variables can be derived from these three.

Once set forth, the simple logic of various population-resource-technology combinations is difficult to ignore. Human beings are critically dependent on their physical environments. As biological organisms, they have certain basic needs, especially food, water, air and some amount of territory. The larger a given population, the greater will be the demands for these basic resources.

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*Nazli Choucri and Robert C. North, Nations in Conflict: National Growth and International Violence (San Francisco, W. H. Freeman, Co., 1975).

In their search for resources, human beings depend upon technology--the application of knowledge and skills. Changes in resource usage are normally an indicator of changes in technology. Changes in technology and resource usage, in turn, bring about alterations in both the natural and the social environments. By making new resources available and yielding new uses for old resources, advances in technology often lead to greater concentration of population. But such advances in technology create their own demands for resources with the result that the margins of energy surplus that are required for stability and sustained growth tend to be variable.

The more advanced the level of technology in a society, the greater will be the kinds and quantities of resources needed by a society to sustain that technology and advance it further. Technologies normally require three types of resources to maintain them: biological and mechanical energy; structural materials for tools, machines, plants and other equipment; and those resources such as food, textiles, metals and so forth that are transported, transformed and distributed for human use.

At least some advances in technology yield greater economies in the transfer and utilization of primary energy[*] and other resources, that is, greater utility of output is achieved for each unit of resource input.[†] Over the great sweep of human pre-history and history, however, each major development in technology has tended to encourage a proliferation of applications and to catalyze innumerable other technological enterprices and uses--each requiring resources for structure (machines, tools, plant equipment), for fuel (wood, coal, oil) or for processing (wool, cotton, iron ore, raw rubber and so forth).

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[*] Hans Thirring, Energy for Man: Windmills to Nuclear Power (Bloomington: Indiana University Press, 1958), p. 21.

[†] Cf. T. K. Derry and T. I. Williams, A Short History of Technology (Oxford: The Clarendon Press, 1960), pp. 319-21.

Advances in technology tend also to increase the amount and the range of what people think they need above and beyond such basic necessities as food, water, air and minimal living space. Rising standards of living mean massive growth in consumption to the point where an average citizen of the United States uses more than a thousand times as much energy per year as the average Burundian or Nepalese. As technologies advance, moreover, even the procurement and distribution of these relatively simple necessities tend to involve larger and larger networks of instrumentalities. Ancient people acquired water by dipping into the nearest spring, river or lake. But today their descendants in a high-rise apartment depend upon hierarchies of complex instrumenalities--all requiring energy and other resources--when they draw the same amount of water from the tap of their thirtieth floor apartments. These considerations mean that in terms of environmental impact an increase of the population of a highly industrialized society by one person may be equivalent to a population increase of up to a thousand in an underdeveloped society.

Social, Economic and Political Institutions on Coping Mechanisms

Both the numbers of people and the characteristics of the prevailing technology influence the way a society organizes itself. Any strong environmental feature or any peculiarity of population, technology on availability of resources that stimulates recurrent behavior, and especially perseverant interactions among numbers of people, influences a society's customs, laws, institutions, and other domestic structures. And, in turn, these customs, laws, institutions and other structures influence, shape and constrain behavior, control resource distributions and regulate relations established in part, at least, by divisions of labor.* As population increases, the percentage of the population in cities tends to increase, and this tendency affects almost every aspect of life.†

Technological development has tended not only to increase the range and amount of resources available to a society, but to influence individual and social behavior as well. Indeed, governmental structures on all levels may be viewed as having emerged, in part, as mechanisms whereby societies at various levels of development have sought to cope with the physical environment, oversee the acquisition, transformation and distribution of resources, and relate to other societies. Major alterations in technology such as the agricultural revolution have contributed to major alterations in the ways various societies have governed themselves domestically and related to each other externally. To the extent that parts of the world may already be embarked on another such revolution--perhaps an electronic and massive energy transformation revolution--the impact of such changes in social, economic and political structures becomes as critical as societal influences upon the relationships of population, resources and technology.

Particular technologies require particular divisions of labor which often become institutionalized, affecting how people live, and often providing the structure for economic, social and political hierarchies. Even the form of government will be affected by the size and density of the population and by the technology and the work people do. Complex feedback effects operate from population, resources, and technology to economics and politics, and from economics and politics, culture and society back to these more aggregate and basic "master" variables. Any marked or significant changes in either the master or the institutional variables will have reverberating effects throughout the system as a whole. To a large degree, the domestic and internal politics of a society, as well as its economics, will thus depend on its prevailing technology, on population-resource-technology ratios and trends, on who controls the society's primary energy and other resources (and by what means), and on its budgetary distributions and other major allocations.

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*See Karl A. Wittfogel, Oriental Despotism: A Comparative Study of Total Power (New Haven: Yale University Press, 1959).

†Lewis Mumford in William L. Thomas, Jr. (ed.) Man's Role in Changing the Face of the Earth. Vol. I (Chicago: The University of Chicago Press, 1956), p. 394; cf. Aristotle in Benjamin Jowett, trans. The Politics of Aristotle (Oxford: The Clarendon Press, 1885), Vol. I, p. 43.

The entire sweep of human pre-history and history has been characterized by larger populations, by more advanced technologies, by the ability to employ larger amounts of energy and other resources for human purposes and by demands for greater quantities and wider ranges of goods and services. Increasingly over time, demands for energy and other resources have escalated because of these overall growth trends. This means that, whereas in the past the growth of a given society or civilization began eventually to press against local or regional resource limitations, the constraints of the future are likely to have worldwide implications.

Such phenomena as resource depletion and environmental pollution are as old as the human species. During the eras of human pre-history, scattered bands and tribes normally solved these problems by moving into new territory. But as towns and cities were established and as sedentary populations grew, communities and sometimes whole civilizations were affected by pollution and depletion problems. The outcomes were varied. In some instances, the nuclear society expanded--peacefully or by conquest--into fresh territories. In other instances, the development of a new technology, such as large scale irrigation or commerce by land or sea, enabled the society to continue growing. In still other cases, the depletion of the soil or other resources (often combined with pollution in various forms) led to stagnation or even the collapse of a whole society or civilization. Historically, however, it has also been characteristic of great societies and even of whole civilizations that--after generations of demographic, technological and economic growth--the spiralling demands of the people have exceeded the depleted supply of readily available resources and the technological capacity for obtaining new resources or for finding new uses for the old resources.

Depletion does not usually mean that a source is exhausted, but rather that the more readily available, the more concentrated, the richer or the higher quality deposits have been used up. Monetary costs will be a critical factor in determining whether a given community or society exploits resources that are near at hand or reaches out beyond its own borders to obtain them by one means or another elsewhere. As the more readily available resources are depleted, is it more economical to develop new capabilities for exploiting harder-to-get substitutable domestic materials, or to acquire them through foreign trade or conquest? In the past, many countries with sufficient naval or military capabilities acquired overseas colonies or protectorates in order to ensure access to critical resources. These tendencies often shaped the expectations, dispositions and policies of new nations emerging from old colonial areas.

In the longer run, the cost of acquiring resources overseas has often become prohibitive to a previously dominant society--either in terms of purchase and transportation costs or in political or defense costs, casualties suffered by expeditionary or occupation forces and the like. Under such circumstances political, commercial or industrial leaders of the dominant society sometimes succeeded in developing new technologies for acquiring the hard-to-get domestic resources more cheaply or for utilizing other resources in new ways.

The demands of a society must be combined with suitable capabilities if effective activity is to be generated and sustained. When demands are unmet and existing capabilities are insufficient to satisfy them, new capabilities may have to be developed. But a society can develop particular capabilities only if it possesses or acquires the technology and resources necessary for creating them. Much can thus be inferred about the probable behavior of a society according to the pattern of its demands and capabilities, including the state of its technology. In this connection, many societies seem to fall roughly into one of the following categories:

Low Technology	High Technology
High population Limited access to resources (China , 1900)	High population Limited access to resources (Japan, 1930s)
Low population Limited access to resources (Afghanistan)	Low population Favorable access to resources (Sweden)
Low population Favorable access to resources (Saudi Arabia)	High population Favorable access to resources (United States--at least until recently)

Each one of these six general types of countries faces its own particular problems. A strong new trend in any one of the three "master" variables--whether of growth or decline--has implications for the other two variables, for the society as a whole, and for its relations with other societies.

Current strains on political, social and economic systems are already very high. Even more rapid changes are likely to take place in the immediate future. The forms and practices of government will undoubtedly be called upon to meet rising demands and the many problems associated with the acquisition, transformation and distribution of critical resources. Until now, however, very little systematic research has been done on the long-range effects of population, technology and access to resources on values, custom, law, domestic institutions, demands, capabilities and forms and procedures of government, and whatever is formulated about such relationships must be accepted as largely hypothetical, if not speculative.

Some Difficulties Inherent in the Analysis and Regulation of Social Systems

Among many social scientists there is a growing consensus that relatively little is understood about how large and complex social systems--including large cities, large public enterprises and large states and empires--really work. All too often, the intuitively obvious outcome of a policy or action does not occur. And all too often, the program that is undertaken to solve a problem has a reverse effect or, in solving one difficulty, creates or exacerbates another.

There are numerous reasons why social systems are difficult to analyze, understand, and control. To begin with, all social systems exhibit equifinality, that is, similar "lines" or "paths" or sequences of behavior often lead to different outcomes, and similar outcomes are often reached by different "paths" or by the same antecedents in different sequence. The consequence is that system structure in many instances may be more important than system state, i.e., the nature of interrelationships among elements may be "more critical than the precision of the input data." Yet analysts and decision-makers alike may be inclined out of precedence and habit to look at "input" rather than "structure." Also, many complex social systems tend to be "stable in response to most changes in input, yet exhibit catastrophic changes in the face of a few gradual alterations in input." And there are often long time lags in the accommodation of systems to change--a tendency that is likely to encourage false causal inferences among both analysts and policy makers. The consequence is that the behavioral outcomes of complex systems often appear all the more unexpected or counterintuitive.*

There are other reasons why scholars, planners, managers and statesmen, as well as the public at large, may misunderstand and misinterpret the nature and behavior of large and complex social systems. "It is my basic theme," wrote Jay W. Forrester a number of years back, "that the human mind is not adapted to interpreting how social systems behave. Our social systems belong to the class called multiloop, nonlinear feedback systems."† Such systems normally involve hierarchies within hierarchies of complicated and often influential feedback loops involving social, economic, political, technological and resource variables.

In the long course of human evolution it has not been necessary for people, until very recent historical times, to understand these systems--or to acquire enlightened control over them. Because of their limited population size and technological capacities and because of the buffering effect of geographical obstacles and sheer distance, societies in the past could do only limited and localized damage to the natural environment and to mankind as a whole. Civilizations could "muddle through" for centuries at a time without intolerable damage to the earth or to the human race. Therefore, experience may not have provided us with the constructs required to interpret properly the dynamic social and political behavior of the systems of which we are not critical parts. As a consequence, a society may suffer "a growing sense of futility" as it repeatedly attacks deficiencies which the symptoms," in fact, "continue to worsen."*

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*Harold A. Linston, "Planning: Toy or Tool?" JEEE Spectrum (April 1974), p. 44.

†Jay Forrester, "Counterintuitive Behavior of Social Systems," ZPG National Reporter (June 1971).

It appears to be characteristic of many contemporary social systems that they have a relatively few sensitive influence points through which the behavior of the system can be changed. Frequently, such influence points are not located where analysts, planners, managers or politicians expect them to be. Furthermore, if a sensitive point has been identified in a location where influence can be exerted, the probabilities often are that a person "guided by intuition and judgment will alter the system in the wrong direction."† In fact, a social system may draw our attention to the very points at which an attempt to intervene will fail. "When we look, we discover that the social system presents us with an apparent cause that is plausible according to what we have learned from simple systems. But this apparent cause may be a coincident occurrence that, like the trouble symptom itself, is being produced by the feedback-loop dynamics of a larger system."‡

Whatever its advantages, every course of action also involves costs which someone must bear. There is no fully satisfactory way of having one's cake and eating it, too. Critical questions relate to how the benefits and costs are distributed within the society as a course of action is undertaken. Also, in any hierarchy of systems, there is often an inherent conflict between the best interests and goals of a subsystem and the best interests and goals of the broader system. The interests will tend to conflict with worldwide human interests, the immediate

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*Ibid.
†Ibid.
‡Ibid.

interests of the unemployed may run counter to the control of overall inflation, the conservation of a local environment may be at odds with a nation-wide demand for oil, and so forth. Yet all these interests and goals may be legitimate and "just" from one or another perspective.*

These tendencies are exercerbated by the conflicts that often exist between short-term interests and long-term interests. The solution of this year's economic problem may be achieved at a cost to the environment that will not be fully exacted until ten or twenty years hence. Pressures for a short-run advantage may lead to a minimizing of the longer-term cost. It is difficult for a living populace to deny itself in the interest of generations that are not yet born.†

In some situations economic growth seems to present another paradox or decision-making dilemma. Unless a nation's production increases year by year, the economy may be depressed. Historically, those societies that have ceased to grow economically and technologically have often declined or been overrun by their enemies. On the other hand, unlimited growth over an extended period may contribute to resource scarcities, pollution, urban stagnation, trade imbalances, international conflicts on various levels and outright war. And seemingly no society can grow forever.

Many difficult contradictions emerge from the fact that populations, resources and technology are differentially distributed among the countries of the world. Strong growth in a country's economy and production capacity may increase competition with other countries for resources, markets and the strategic advantages considered necessary for securing trade routes. While seeking to strengthen its own position, each country

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*Ibid.
†Ibid.

tends to validate the competitive anxieties of its rivals. As resources are depleted or markets flooded, each of the countries is likely to redouble its efforts, thus exercerbating demands and possibilities for conflict.

In recent years this paradox has developed new and complicated dimensions. Before World War II, and to some extent thereafter, the industrialized countries of the world were able to obtain protected access to resources and markets through the acquisition of colonies, and the acquisition of colonial territory is no longer as feasible. The social, economic, political and military penetration of these so-called underdeveloped countries has accordingly become more sophisticated and more critical--with the realization, by strong and weak societies alike, of the need for secure access to energy and other resources in a world of scarcities. Increasingly, also, a number of weaker countries are beginning to perceive possibilities for increasing their power and influence by vigorously controlling and regulating access to their domestic resources by the industrialized countries. This possibility adds to their potential influence in world monetary affairs, in conferences dealing with sea bed resources, in debates and critical voting procedures of the United Nations General Assembly, and in the proceedings of other international agencies.

Our understanding of social systems and how they work is impeded by the complicated ways in which actions often relate to each other. Actions are so commonplace in human affairs that we often take them for granted, scarcely bothering to define what they are. In fact, what we often identify as a single action turns out to be a complexity of actions within actions within actions, so that what is referred to as the act or action is only that aspect which creates the most immediate impact upon the human senses, or its amounts to a conceptual shorthand for a very complicated phenomenon such as the overall effort to generate a "green revolution" in South Asia.

For an actor A to do something to actor B (or to the general environment C), he--A--may have to do something else, "not subsequently, but in order to initiate, continue or complete his action." The activities of an individual can thus become extremely complicated. Clearly the decision of state, community, firm, nation state or other large and complex social system is even more complicated than the activity of a single individual. In any inclusive action or activity the smaller, component action units may be viewed as "molecular" and the larger ones as "molar."* The molar units are thus composed of molecular units. This suggests that "we are trying to describe a process that is organized on several different levels."†

With respect to organizational as well as individual behavior, a molar activity may have consequences as a molar unit which are not the same as the consequences of the molecular units it includes.‡ In view of these complexities--and the potential for "side-effects" and other unanticipated and unwanted consequences--it is unfortunate that much analysis and decision-making focuses upon the intended outcome of the "molar" activity, but not upon the possible effects of the various molecular levels of activity. In parts of South Asia, one effect of the molecular activities associated with the implementation of the "green revolution" was to encourage the capitalization of well-to-do farmers and various entrepreneurs, while the poor peasants found themselves even worse off then before. Thus, the previous interactions of an individual, community, firm or nation state with the natural or social environment may have a powerful effect on subsequent interactions. This is an important reason why changes in environmental policies are often extremely difficult to implement.*

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*George A. Miller, Eugene Galanter, and Karl H. Pribram, Plans and the Structure of Behavior (New York: Henry Holt and Co., Inc., 1960), p. 13.

†Isidor Chien, "The Image of Man," The Journal of Social Issues, Vol. XVIII (1962), p. 11.

‡Ibid.

Because of the hierarchical arrangement of many actions, it also happens that a molar activity becomes a motive for the molecular activities it includes. Flood control--an undeniably worthy enterprise--may provide the motive for lining natural streams with concrete; the mining of much-needed coal motivates the stripping away of forests,and topsoil; and so forth. In some situations, a behavior may even "become a motive of the behavior that initially motivated it."† Thus, since economic growth may contribute to a country's power and because a powerful country may find new opportunities for growth, growth and power-seeking may become reciprocally motivating--perhaps at the expense of other societal values.

Perceptual problems complicate growth-competition situations within and between societies and contribute to another subtle, but very powerful type of problem. No human being, including a head of state, can even know for certain how his own actions will be responded to or interpreted by another human being. And, in turn, he has no way of ascertaining beyond any doubt what the other intends by his actions. He can only infer such predispositions and intentions by what the other does (or has characteristically done in the past). Obviously, there is no single, best way of getting at such problems or of understanding better some of the counter-intuitive aspects of nation-states and other large and complex social systems. But to some extent, they can be attacked through

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*Ibid., p. 10.
†Ibid., p. 17.

computer modeling, simulation and forecasting. Several such techniques have been put forward in the last few years as tools for achieving a better understanding of how social, political and economic systems work.

The objection can be raised that ultimately the critical problems of resource usage are issues of human value that statistical techniques tend to by-pass. There is some truth in this allegation, but there are ways in which linear programming, modeling, simulation, and forecasting can be used to identify and illuminate values rather than obscure them. Linear programming, for example, has been used in the past to optimize war-time logistics, and to maximize commercial profit. It has been used less often to optimize broader environmental or social outcomes.

Values are implicit, if not explicit, in all human decisions; the problem is, how to identify them and link them with particular decisions, actions and outcomes. A crucial step in this direction involves the distinction between professed values and what may be referred to as operational values. In the analysis and operation of social systems there has often been a great deal of confusion about professed as opposed to operational values. Speeches, interviews, public relations handouts, memoires, the preambles of treaties and other state documents yield professed values in great abundance, and all too frequently they are accepted as true values. Frequently, such data indicate much about what a head of state, legislator or other national leader likes to think he subscribes to or what he wants the public or the leaders of another country to think he stands for, but very little about what he actually does. In general, the record of the decisions he has made in the past (and the values thus operationalized) will be more accurate predictors of what he does in the future.

Any increase in a country's population is the outcome of a conscious or unconscious "decision" on the part of at least two people to have a baby. Each invention and each technological refinement is also the result of human decision, as is each movement of goods, each budgetary allocation, each investment, and so forth. And to the extent that each datum represents the outcome or trace of a decision, some value or set of values is also implicit.

A country's annual budgetary allocations are a useful and accurate measure of the society's operational as distinguished from its professed values. Of course, one cannot conclude that all the citizens of a country necessarily approved the allocations that were made or shared in the values that were invoked. But the statistical data do tell us, beyond any doubt, what values were in fact acted upon by whatever individuals or groups were responsible for that country's investments and other expenditures.

Through causal modeling, simulation and retrospective forecasting the analyst or policy-maker can infer with a high degree of confidence what values a given society has acted upon with some consistency over a period of forty or fifty years in the past. A projection can then be made on the assumptions that past trends, and the values invoked to produce them, will be continued for thirty, forty, or fifty years into the real future. Having achieved this base-line forecast, or projection, on the basis of very explicit--though perhaps unrealistic--assumptions about the future, we can use sensitivity analysis or linear programming to introduce alternate values--and observe the probable outcomes. Moderate or massive changes in energy and other resource usage can be introduced and the probable consequences observed--with the rates of change of other critical variables altered or held constant. Theoretically, all possible combinations can be tried out.

For each alternative, the effort should be made to ascertain not only what social benefits and costs are likely to be, but also how these benefits and costs are likely to be distributed within the society or between societies. In this way, not one or a few, but literally thousands of alternative futures can be generated with all assumptions and each introduction of a new value recorded and made explicit. It will be possible to introduce a new value in country A's decision-making and watch the outcome not only for A, but also for countries B, C, D, et al.

Research Needs for Anticipating the Impact of Changing Resource Usage

To understand the environmental impacts of changing resource usage, it is necessary to examine the ways in which such changes are linked with the levels and rates of change of population and technology--as well with various social and political variables. In these terms, politics not only bears on ecology but will increasingly involve the regulation and management of population growth and distribution, of resource usages and allocations and of technological advancement and applications,[*] including the control of pollution. The modes and characteristics of prevailing resource usages may be expected to influence--and be influenced by--levels and rates of change of population, the technological advances, and social, economic and political mechanisms.[†] The modes and characteristics of resource usage during an earlier period may also be expected to influence resource usages in subsequent periods.

Fortunately, we need not wait for challenging events to take place before addressing ourselves to them in systematic ways. Tools are now at hand to identify various important linkages, to simulate historical process, and to generate future alternatives. Appropriate data are generally available, although much is of uneven quality, and great improvements need to be made in social and political indicators. The application of econometric, system analysis and operations techniques to social and political as well as technical and economic problems may help us expand our thinking and thus facilitate "social learning."

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[*] Harold Lasswell, Politics: Who Gets What, When, How (New York: Meridian Books, 1958).

[†] Walt Anderson, ed. Politics and Environment: A Reader in the Ecological Crisis (Pacific Palisades, California: Goodyear Publishing Co., 1970).

Previously, unlimited growth and expansion have provided solutions to certain human problems. Today, however, many people see growth and expansion as "part of the problem"--although others are equally disturbed by the prospect of a low-growth economy. Is there an unambiguous answer? It is entirely possible that whatever we do in trying to anticipate tomorrow's problems, we may once again set the stage for future difficulties. The equifinal nature of human affairs rules out certainties.

Ultimately, the course of events will depend heavily upon the assumptions that are accepted. It is therefore of utmost importance in both research and policy making to make operational assumptions as explicit as possible. To a large extent such assumptions depend upon past experience which can be elucidated through the application of appropriate research strategies. Alternative theories and models can be tried out--with the result that the implications of different sets of assumptions can be made somewhat more explicit and their implications systematically explored.

The course of events will depend also upon the values that are evoked and acted upon. Who is to decide upon the alternatives that are to be considered preferable--and why and how? Should "multiple advocacy" be combined with "multiple theories," "multiple models" and "multiple methodologies"? Is "multiple advocacy" desirable, and if so, how can it be institutionalized? And if a strategy of "multiple advocacy" is followed, how is it decided how the ultimate choice will be made?

With an appropriate conceptual framework, new tools, and access to data it should be possible to provide a favorable context for answering". . . if this then probably that. . ." types of questions. What are likely to be the broad social, economic and political (as well as technological) outcomes, for example, if current (baseline) trends are projected to the turn of the century or beyond?

If current trends of variables other than resource usage (population, and so forth) are held constant, what are likely to be the direct and derivative impacts (social, economic and political) of various possible petroleum, natural gas, coal, geothermal, nuclear and other programs? What could be the social, political, economic and environmental complications of a major breakthrough in solar energy or fusion? To what extent will the further development of each of these programs increase or reduce demands for scarce minerals and other hard-to-get resources. What are the implications for food production, quality of air, availability of fresh water and so forth? Can some of the "unanticipated consequences" of each of these resource strategies be identified in advance? What are the implications of relatively equal as opposed to grossly unequal access to critical resources within given countries and among countries throughout the world?

Since most of these questions have worldwide, as well as domestic implications, what are likely to be the effects upon international trade? The international monetary system? International relations, including international conflict and warfare? What are the implications for resource usage (and its consequences) of continuing competitions in nuclear weaponry? What are the domestic and international implications of the exploitation of the continental shelf and the deep sea beds? What are the possible tradeoffs in terms of various international divisions of labor relating to resource usage?

To what extent can "steady-state" economies be developed--and would they be desirable? Can industrialized countries learn anything from the "Buddhist economies" put forward by E. F. Schumaker and others?* In what new ways can the principles of inverse feedback be used to combine regulated growth with stability and environmental protection?†

To the extent that alternative responses are obtained to basic ". ...if this then probably that" kinds of questions, a foundation and context will exist for the discussion of values, options, compromises, optimizations and tradeoffs and the solution of more specific or narrower, perhaps more technical problems of concern. But if we want even reasonably adequate answers, most fundamental issues of the future need to be raised and examined within a context which brings biology, engineering, economics, politics, ethics and other disciplines into systematic relationships with each other.

More often than not, major redistributions of benefits and costs have been an outcome of major disruption and violence. Is it possible to design and subject to controlled testing various new institutions and other mechanisms for achieving--peacefully and with less disruption--some more stable and equitable distributions of benefits and costs?

Modern economies illustrate some of the problems that we face. In many respects economies today are the most developed and rigorous of the social science disciplines. But rigor has not been achieved without cost. To a large extent, economists have achieved success by holding a great many "soft" variables constant, or even assuming them away. This tendency has contributed to the strength of the discipline, but it can

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*E. F. Schumaker, Small is Beautiful (New York: Harper Torchbooks, 1973).
†Jack C. Page, "Engineering Social Systems," Technology Review, Vol. 74, No. 8, p. 43 (July/August 1972).

be costly--perhaps even catastrophic--in terms of solving human problems. Indeed these "soft" variables are precisely those which pertain to human motivation, perception, cognition, feeling, value, preference, decision and policy. To a considerable extent it is these "soft" variables that tend to guide and influence the outcome of economic and engineering variables. A major effort needs to be made in the direction of expanding essentially economic models to include various "soft" and exceedingly "messy" social and political variables.

Since resource usage, technology and work methods are continually changing as human capabilities and values change, the nature of any given economy tends also to change and to generate new characteristics and new requirements.* However, in view of several basic assumptions that underlie the discipline--contemporary economics tends to perpetuate certain biases, not always made explicit, with respect to how societies have been, are now, or might be organized and managed. In this connection, some of the ideas put forward by Schumaker could well be considered and extended.†

Within this broad conceptual and methodological framework a large number of specific issues can be examined. The few that follow are only illustrative:

1. In a recent article entitled "Lifeboat Ethics: The Case Against Helping the Poor,"‡ Garret Hardin has argued that foreign aid to "improvement" and "ineffective" countries with large and growing populations should be ended, allowing such societies, in effect, to sink or adapt.

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*P. J. Bohannan, Social Anthropology, p. 321 (New York: Holt, Rinehart and Winston, Inc., 1963).

†Schumaker (1973).

‡Psychology Today (September 1971).

What would be some of the highly probable economic and political effects of a Life Boat policy on the United States, other countries and the world at large? What other "models" might be tested?

2. A great deal more work needs to be done on social indicators--including the devising of new means for measuring social well-being and the overall quality of life. GNP, useful for many measurement problems, can be misleading as an all-purpose indicator. It would also be useful to examine ways of distinguishing "needs" from demands. How can the problem of "need" be handled equitably across national and cultural boundaries? Is it fair to assert that the satisfaction of "needs" in the United States places a much greater strain on the environment than the satisfaction of "needs" as defined in Bangladesh or the Sahel?

3. If rising prices for foreign oil were combined with a series of drought years in the Soviet Union or elsewhere, what would be the effect in terms of marginal land use in the United States? What would be the domestic and foreign consequences of a competition for marginal land between grain-growing interests in the United States and domestic energy extraction interests? How much arable land can we afford to mine or urbanize?

4. The acquisition of foreign exchange surpluses by OPEC countries has already effected a shift in world wealth. What would be some of the future implications--diplomatic, political, economic, and military--for the United States if this trend were to continue at present rates? At an accelerated rate? What are the potentials for an "economic war for survival"? Would the United States be prepared to protect Japan and the NATO allies--as well as itself--from extortion?

5. Are there grounds for the assertion that an oil exporting country that is also a food exporter has the possibility of dominating the world in many ways. How?

6. At a time when various peoples of the world, including revolutionary groups and dissident minorities, are becoming increasingly aware of and vocal about unequal access to resources both within and between countries, new types of weapons are becoming increasingly available which are useful not only for guerrilla warfare but also for political assassination, highjacking and political-military blackmail. It would be entirely possible for such a group to present a country like the United States with the choice of sending food or losing Chicago. These possibilities suggest a range of psycho-political-military topics that need investigation.

7. What are the correlations, if any, between world energy flows (production, consumption, imports and exports) and world arms flows (production, consumption, imports and exports)? What effect are rising prices for energy likely to have upon the manufacture and distribution of arms, arms expenditures, and efforts to control arms?

8. To what extent, historically, have the defense of trade routes and the securing of access to critical resources contributed to warfare in major ways? What are the possible implications of such dynamics in a world where demands are skyrocketing and readily available supplies becoming scarcer?

9. How can the social, economic, and political feedbacks of technology transfers--the exportation of the "green revolution" to Indian providing an historical case--be monitored and analyzed systematically in terms of positive impacts and also unanticipated and possibly unwanted side effects and other consequences?

10. China--which used to be considered energy-poor and where only twenty-five years ago millions of people starved annually--now seems able to feed itself and export energy at the same time. We need to

know more about Chinese methods and their domestic and foreign implications and impacts.

11. In case of a major breakthrough, what would be the implications of massive supplies of solar or other energy, more or less equally available for all people, in terms of employment, traditional work and leisure ethics; competitive economic systems, and so forth?

12. By analyzing trends in various countries over the last thirty years in terms of population, technology, resources and their characteristic patterns of allocation and distributions, it should be possible to ascertain more as compared with less desirable combinations or ratios of the major variables in terms of quality of life. For any particular country, in view of its territorial size, geographical location and so forth (1) what would be an optimal population for a given level of technology, or (2) if population is accepted as a given, what would be an optimal level of technology and production, or (3) if access to resources is constrained, how could technology, production and various other domestic allocations be adjusted or modified in the shorter run and population reduced in the longer run to yield an optimal quality of social, political, and economic life?

These are only a few of the many problems that confront us, that are important for the future and that are best investigated within a broad interdisciplinary framework.

REVIEW OF THE PAPER BY R. C. NORTH

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In the first half of his paper, Professor North has given an extremely interesting and useful explanation of the interrelationships among population, resources, and technology; and the manner in which they have feedbacks to social systems, politics, cultures, economic systems, commodity and resource demands, and environmental quality. He emphasizes appropriately the greater complexities of these interrelationships and interdependencies as societies become geographically bounded by space and cannot move on to other locations or draw down from other countries as their populations enlarge against given resources. It is, of course, this set of interrelated variables and conditions which give rise to our crises of resource demands against supplies (e.g., energy) and to growing problems of environmental quality.

He is correct that these complex systems are difficult to analyze and that policies frequently fail because they do not encompass a sufficient number of variables or facets of these complex systems representing interactions among population, technology, and resources. However, I do feel more optimistic about research possibilities and potentials than is reflected in the last half of his paper.

Professor North touches on an extremely broad range of problems and variables. Some of them are closely related to problems of environmental impacts linked to changed patterns of resource usage, while some are only remotely so. He discusses, in this single paper, the more conventional environmental set of variables but also devotes considerable time to

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problems surrounding energy, international exploitation of developing countries by developed nations through shifting from colonies to markets, the green revolution in India and others--without indicating clearly how these are part of the core environmental problem set. The paper does not "focus down" very clearly or sharply on environmental problems or issues, or on where and how interdisciplinary research can be organized and directed to solving them (although this was a major element in the title of his paper). But perhaps there is some merit that he did not do so since his range over a broad set of problems and variables, not all closely linked into the core problems of the environment, indirectly suggests how difficult it is to understand social systems--either in how they react to new stimuli or how they can be controlled to attain various goals or ends.

He is indeed correct in emphasizing the complexity of these social systems. He appropriately outlines their hierarchial nature and the conflicts of interest generated therein. Further, he is certainly on sound ground when he emphasizes the interdisciplinary (or multidisciplinary) nature of environmental problems and their cause or solutions. Unfortunately, however, he did not provide a systematic outline or model of how and where interdisciplinary research can be organized to allow either (1) better predictions of environmental impacts in changed resource usage or (2) solutions of problems and impacts that are already evident and are unwanted. Is this void due to the complexity of social systems, including our universities and research institutes, which provide ineffective means for integrating the research of different fields of social science and of social science with physical, biological and engineering sciences.

He correctly indicates that the different sciences, and even fields within given sciences, have increasingly insulated themselves from each other. The reasons for this are quite obvious and need not exist. They exist for a collection of reasons causing scientists in one discipline or field to talk to each other through their own journals, rather than in solving problems on a multi- or interdisciplinary basis. Part of the reason for this "tighter trend" stems from the administration, research, and graduate deans or universities and research institutes who (1) hold back promotions and salary enhancements unless researchers publish in their journals, (2) will not promote personnel to graduate colleges unless they publish single-authored articles in referred journals, (3) give little or no weight to a mimeographed or multilithed paper by a team of scientists rushing research findings out to solve the problem of a community or set of administrators, and (4) other actions and restraints.

True, these complexities prevail and Professor North seems pessimistic throughout his paper. However, I believe there are means for organizing multi- or interdisciplinary research for better prediction of environmental impacts from changed patterns or greater usage of resources, or in solving negative impacts that now prevail. I have long worked on an interdisciplinary basis and do not find the insulation that disciplines and fields have thrown up around themselves to be insurmountable. In fact, it seems easier to work on an interdisciplinary basis with personnel of physical, biological, and engineering sciences than with those of other social sciences. I am a bit puzzled as to why this is true. Perhaps, in my case, the methods of research and models available and used by economists more nearly parallel those of biological and physical scientists than other social sciences. But to be specific, I also believe that other social sciences can beneficially draw on those same methods and models--and at a later time will do so much more than now.

I now turn to means of overcoming the barriers and insulation that scientists have thrown up around themselves that prevent them from a direct and integrated attack on priority environmental and social problems. One barrier is the organization of our universities and colleges by disciplines and fields therein, with budget power allocated accordingly. This problem can be solved, and has in some instances, through an organizational matrix which has disciplines as columns and problems as rows. The rows have as much control over budgets and personnel as do the columns and they become integrated accordingly. Interdisciplinary research can be encouraged by university administrators who insist on the importance of the problem, rather than discipline purity, and organize teams accordingly. Administrators can encourage it through the reward system which amply favors a person whose name appears with a group of others on a publication appearing elsewhere than in a "pure discipline journal." (Our current reward system tends to be the inverse of this approach.) The grantor of research funds can both suggest and insist on an interdisciplinary approach and require that it not be just a "paper proposal" for the same but is, in fact, exercised as the project is implemented. When university administrators or donors of research funds become serious enough, they have in their hands the means of generating and implementing the interdisciplinary research almost always involved in major environmental problems.

The individual scientist also can accomplish much more than he believes, if he is willing to amble across the campus or to the next floor of the institute and try. I have done much interdisciplinary research with physical, biological, and engineering scientists over the last 20 years. I have yet to register a failure when I decided I wanted to work interdisciplinarily on a problem. I have almost always done it outside of a formal project or contract. I have accomplished it by explaining in detail the importance of the problem and the methodology to be used. Quite frequently the methodology has involved concepts (e.g., a production function), research designs, and models which are rather foreign to the biological, physical, or engineering scientists and he has been challenged to attempt it.

Thus, while the various scientific disciplines have increasingly tried, or have been successful in, isolating themselves from each other, I am much more optimistic than Professor North in our potential ability to mount interdisciplinary teams to tackle problems of environmental impacts. Some of our universities, particularly state or land grant universities such as the one in which I serve, were created to serve the public and help it in decision-making processes and in solving its problems. Generally, they have good records in doing so and in carrying the results of research to the public through the cooperative extension service. In my state, we have a long history and tradition in carrying policy analyses to the public--to help aid in choice and decision, not by prescribing a one alternative solution but by explaining the tradeoffs among alternative policy attainments or different means to attain a given policy end. If the public finds that state or land grant universities (the research and educational arms of the public) are void in organizing interdisciplinary teams to better predict environmental impacts or to solve the problems they have generated, it has a means to right the situation through the funds it appropriates or through the program administrators it employs. While we have too little interdisciplinary research, we certainly have some, and both the public and university administrators have within their grasps means for attaining more.

I again express my optimism for the future, at least between economics and the biological, physical, and engineering sciences, since increasing knowledge and application of the same or similar quantitative models fall in the domain of these different sciences.

One obstacle in organizing useful interdisciplinary research for practical evaluation of environmental impacts is the extremely short-term and hurried projects under which the EPA extends its contracts. The time constraint on many of these is so great that at best a "slap dash" study must be thrown together, drawing mostly on the basis of what is known or can be systematically "drawn out of the air." At best, these "quickies" must be done mostly with models and data that already exist. They give little time for specifying original interdisciplinary models and in generating data for their application. An interdisciplinary approach typically requires considerable pre-study and various seminars among groups of persons. This added time for seminars and knowledge buildup steers some people away from interdisciplinary approaches (they say they can do more quickly on a lonewolf basis) and is a step which is nearly impossible under the short timing of many EPA contracts.

Progress in Modeling

I believe the progress and potentials in modeling to predict or evaluate impacts of technology and changed mixes and levels of resource inputs on the environment have progressed further and are more readily applicable than is suggested by Professor North. Of course, his emphasis tends to be on overall social systems where the task is admittedly difficult, but he overly discounts the extent to which various types of models have been applied and the further potentials for applying them. For example, he states "Linear programming, for example, has been used in the past in order to optimize wartime logistics or kill ratios, or to maximize commercial profit, or to serve the special interest. It has not been used as often as it might to optimize broader environmental or social outcomes."

Actually, linear programming has been used broadly over the last dozen years to evaluate alternative policies and social and environmental outcomes. My colleagues and I used the method broadly during the 1960s to evaluate alternative farm policies and generate the tradeoffs in food costs, treasury outlays, farm income, export potentials, rural employment, and other "outcome variables." We have evaluated nationally and simultaneously by 150 regions the impact of large and small farm technology on farm numbers, total farm income, income per farm, chemical and other nonfarm input usage, farm prices, consumer food costs, rural community employment and income generation. We have applied a national water model which evaluates alternative techniques, the substitutability of land and water and certain environmental restraints in determing the availability of water for food production, export tradeoffs and urban and industrial uses in the future. We also have a very large-scale environmental model of the entire United States for the land and water resources of agriculture which extends up to 10,000 equations and over 100,000 variables relating to 1,891 land resource regions, 50 water supply regions, 35 consumers markets, all commodities produced and all technologies used in agriculture. These models allow simultaneous evaluations at the national, regional, watershed, state and other levels of technologies, and land and water use practices on the environment. They allow us to examine pollution levels or potentials in the absence of restraints on soil loss or sedimentation, chemical fertilizer and pesticide use, or animal waste controls. Similarly, they allow, region-by-region or nationally, evaluation of outcomes when soil loss, nitrogen and phosphate application, pesticide use, and animal wastes are controlled at various levels. They are capable of quantitatively measuring income redistributions among regions and producer groups as alternative environmental restrictions might be applied. All of them indicate tradeoffs in environmental attainment, farm prices and incomes, food costs, commodity exportability, resource conservation, resource values, and related "output variables." Finally, linear programming models have been used for evaluations in particular watersheds and many other problem areas which impinge on society. While Professor North may be correct in stating that linear programming has not been used enough, I believe that he is either unaware or discounts too greatly the extent to which it has been used to generate information for public choice.

In general, I believe our ability to model large systems has progressed further than Professor North suggests--particularly in the physical, biological, engineering, economics, and demography fields. Less progress has been made in other fields of social science but also I believe the attempts have been fewer and more scattered. Hence, I am more optimistic than Professor North that we can both (1) model these systems, and (2) use interdisciplinary teams in doing so.

I do not understand why he separates and distinguishes between linear programming, modeling, simulation, and forecasting; I find this distinction unuseful. Linear programming, simulation (either systems simulation or econometric simulations) and forecasting all involve specifying a model then generating data to make quantitative application of the methods. Typically, forecasting involves modeling of a behavioral system, and a great amount of it has been accomplished in econometrics. In fact, we have modeled a recursive econometric simulation model for the agricultural sector, which allows evaluation of alternative futures and indicates the tradeoffs of different policies as they impact on soil loss, chemical and pesticide use, commodity prices, consumer food costs, export potentials, treasury costs, and so forth. A model is not separate and distinct from mathematical programming, simulation, or statistical regression forecasting. Also, whereas Professor North correctly points out lags in choice and decision, but seems pessimistic in handling it, lag in decision processes also can be modeled through different quantitative approaches. Use of distributed lag regression models to reflect delays in decision have been rather widely used. Similarly, recursive mathematical programming models have been used to reflect restraints on the rate of change in technologies, resource use and decisions as reflected by a milieu of conditions giving rise to uncertainty.

In the realm of environmental regulations, perhaps there is great need for developing and applying more distributed lag or recursive models so that we can measure and express the tradeoffs or advantages and disadvantages in (1) moving to certain environmental restraints on a step-by-step or slower basis, or (2) making them fully effective at one discrete time. I doubt that all segments of society are able to adjust to change as suddenly and discretely as EPA regulations sometimes suppose. Hence, I suggest that research is needed which employs models with distributed lag and recursive characteristics to better outline the alternative rates or paths of adjustment and imposition of environmental controls. The distributed lag nature of adjustment, and the greater long-run than short-run elasticity of response may have positive as well as negative implication.

Professor North mentions several times, seemingly with considerable despair, that solution of one problem by one means typically causes one or more other problems to appear elsewhere. For example, urban renewal may create new ghettos, welfare programs may produce more crimes, industrial growth conflicts with environmental production, and so on. Rather than despair over these multiple outcomes stemming from a policy, as I believe is implied in his paper, I suggest that they present an immense research challenge and an area that is insufficiently exploited in the imposition of EPA regulations. Rather than accept the notion that "there's no reason to take action on a problem because its solution may cause emergence of another problem," I recommend that more research effort be devoted to analysis of the joint-production multiple outcomes that result from specific environmental policies, technologies, or mixes and levels of resource inputs. Models and means exist for doing so.

However, EPA is taking actions where these tradeoffs have neither been inventoried or measured. They need to be inventoried and measured so that compensation can be paid sacrificing groups and individuals in extreme cases. We do try to measure these tradeoffs in our national and interregional environmental models. Under circumstances of reducing chemical fertilizer and pesticide inputs we find (1) that total farm income increases because supply is decreased and demand is inelastic, (2) farm unit costs are raised to the individual farmer and his independent profit maximizing alternatives are restrained, (3) the environment is affected positively, (4) food costs increase to consumers, (5) the supply price of export commodities is increased and export quantities are decreased, and (6) farmers in areas of limited rainfall less dependent on chemical fertilizers tend to gain relative to those in humid areas. In a similar vein, multiple outcomes of a technology or policy prevail for other resource uses affecting the environment. I suggest that this is a priority area of research for EPA; that we know too little of these tradeoffs and more should be invested in research on them. Economizing in resource use where multiple products are involved, as they always are in the process of allocating scarce resources, involves a negative sloping (and even concave) production possibility curve; indicating that as more of one goal and/or objective is attained another must be sacrificed. The rate of sacrifice (the marginal rate of substitution or the first derivative of the production possibility curve) itself may increase as one goal or product is increasingly pursued. Yet these are rather standard concepts open to model specification and quantification. I reemphasize that they are not reasons for despair, but are entirely researchable and represent realms of knowledge where EPA is yet in extreme poverty.

I tend to view other problems and research areas in this more positive realm--in the sense that they are concepts that can be modeled, quantified, and used to make environmental controls more acceptable than many now are. Also, the ability to conceptualize them rather readily and research them can provide information elsewhere where EPA and society are in great poverty of knowledge and need the supply increased if environmental programs are to be equitable in their distribution of costs and benefits. Professor North does mention systems that possess both micro and macro components and relationships in a systems hierarchy, and that what is good for a subsystem (i.e., a micro component) does not always result in a positive product for the macro or complete system. This is the crux of the environmental problem. Elsewhere, it is given the term of externalities. The large-scale feedlot can lower its costs by letting its livestock wastes be transported by air and water to other points where other entities of society pay costs through a damaged environment. These are costs which are external to the firm, or micro unit. If forced to pay them, its decisions and resource or product use and mix would often be different. Iy is the case of the industrial plant and fixed point pollution or the city delivery truck and its use of fuel and throw-off of exhaust contaminants. In some cases, the extent and nature of these externalities are evident and simple steps to cause the producing entity to suffer their incidence and cost are available and evident. In other cases, the situation is much more complex, the need for compensation to prevent severe income and capital losses prevails and much research is needed to identify and quantify the extent.

I believe that existence of a hierarchy of systems does not preclude progress in environmental improvement but poses great need for research where we now have too little knowledge. I will cite some examples. Numerous environmental restrictions now being posed or already legislated stand to reduce greatly the value of resources and income streams for private property owners. For example, Iowa has a soil conservancy law which, if fully and actually implemented, would restrict sedimentation and soil loss to five tons per acre per year. But the outcome, as reflected by an analysis we have made through our national models, would cause the income of Iowa farmers to decline while returns to farmers elsewhere in the nation would increase. This outcome prevails because food demand is inelastic and a reduced supply enhances total income, but distributes the increment to farmers in stares other than Iowa.

A somewhat parallel case is that where a farmer has been using pesticides and chemical fertilizer over a long period. Society or consumers at large have not previously placed a positive or negative weight on improved environmental conditions relating to these inputs. Accordingly, he uses them and the return is capitalized into his land resources. Now, suddenly society or EPA decides they are going to restrict or eliminate his use of chemicals and pesticides. Since his income flow and asset values will thus decline, it is possible that the sum outcome need not be positive--unless we can prove that the gain in utility to the rest of the community in society is greater than the loss in utility to the farmer. Interpersonal utility comparisons are generally impossible and the only way we can guarantee a positive sum outcome is to compensate him for his loss in income and asset values in refraining from use of these particular resource inputs.

The conflict between micro and macro or subsystem and total system outcomes complicates the implementation of environmental restraints, but it does not complicate research in measuring these externalities and redistributions and in devising means of compensation which will cause them to be equitable and acceptable. EPA is charged with action programs to be implemented under a great void in knowledge of the distribution of benefits and costs involved as these programs are discretely put into effect. This void in knowledge causes programs to be enacted on persons and localities which impose no external costs or sacrifice on others but must pay costs or restrain resource usage as if they did. For example, at a point of time in the future, car and truck owners in the thinly population areas of the Great Plains will suffer incidence of costs in atmospheric pollution control as if they lived in New York, Washington, D.C., or Los Angeles.

Distinction needs to be better made between the location and time of the resources and technologies and their creation of externalities.

I mentioned the case of the farmer whose income and asset values are reduced because he is siddenly restricted from using certain toxic inputs. I proposed that compensation could readily be due him if we were to be certain of a positive sum outcome in welfare. However, if a new technology which he has never used appears on the horizon and promises similar toxic effects or externalities, it is a different case. Preventing him from using it does not depress his existing income and asset values, and compensation hardly seems equitable only to cover this opportunity cost foregone.

EPA operates with a void of information about externalities, cost, and benefit distributions and compensation needs or justification. Environmental enhancement could be made much easier if this void were even partially overcome through research which can be rather readily conceptualized and implemented. We are using our large-scale models to do so for the agriculture sector, the major user of the nation's land and water resources. It is not an impossible complex task in which we must throw up our hands in despair. Frequently, the distributions take interesting twists. We found, for example, that if all farmers were required to restrict soil loss per acre per year to 10 tons (since sedimentation is the major pollutant of streams and also serves as the transportation mode for nitrates and phosphates) farm and rural area income would be greatly reduced in the Southeast because of soil topography and more abundant rainfall. But at 10 tons soil loss, farmers in the Great Plains would have increased income because U.S. total food supplies are lessened, demand is inelastic and this region has scant rainfall and a greater proportion of level land. At a 5-ton loss limit, however, the Great Plains also would have to change its technology rather drastically and experience an income decline.

Professor North discusses conflicts between short-run and long-run interests. The concept is a standard one in economic analysis:

discounting future income streams to arrive at present capital values of different alternative future investments. It is not a difficult problem to conceptualize and model. Discounting under alternative interest or discount rates can even be incorporated into recursive mathematical programming or other models to evaluate different policies or subsidy and compensation schemes to encourage conservation of resources for the future. In Scandinavian countries a complex of tax rebates, special low interest rates tied to the purpose, and even subsidies on plantings are used to encourage tree farming--an activity which does not result in a product until 30-50 years, as compared to an immediate income from annual crops.

Certainly means do exist which can cause conservation or protection of resources to take on priority equal to or greater than current use. It is a topic subject to research and should relate to the consumer as well as the producer. The consumer typically speaks to the producer in one manner or signals one use of resources through the market mechanisms; whereas he also may hold an opposite set of preferences which cannot be expressed through the market. Policies expressed through subsidies or monetary compensation may then be required to offset the consumer's signal through the market. Soil usage is an example. Consumers with higher incomes place heavy emphasis on row crops and feed grain production to produce fed beef. The row crops encourage soil erosion, sedimentation of streams, and proliferation of animal wastes. These negative products are produced because the consumer causes this mix to be the most profitable use of resources. The food producer does not exploit the resources because "he is a bad man acting against society's long-run interests and well-being." However, the consumer may simultaneously wish that the streams be kept clear and that land productivity be preserved for future generations. He has no way to speak through the market for these outcomes and offset his market signal that the land should be devoted to eroding row crops and fed beef. However, he can vote appropriations which allow the public to pay the farmer to cover the land with grass and market grass-fat beef at lower suppy prices.

Many problems of environment and use rates of stock resources fall into this realm of discounting the future and speaking through the market mechanism relative to preferences which the consumer cannot express. It is an extremely important research area. In contrast to ongoing EPA policy, which in majority supposes that the producer or transformer of resources into consumer products is a "bad guy" who should suddenly and fully bear the costs of improved environmental conditions, it is one which has been highly overlooked but should be researched much more in the future. Similarly, research or efficient policies to better reflect and attain consumer and societal preferences, which cannot be reflected through the market or are negated through heavy discounts of future returns, should be undertaken on a rather broad scale.

In summary, I believe that EPA needs a much broader and longer run research program covering the economic and social impacts of various programs to alter and conserve resources and to protect the environment from damaging technologies and resource use patterns. EPA research contracts almost seem based on the assumption that the organizations has two years of existence--within which it must obtain all research answers and impose all environmental restriction forever on producers and resource users. The result is too many very short-term research projects so strongly restrained by time that their products must be small and incomplete. Not infrequently the research contract period is so short and the problem is so complex that the time allowed is not long enough to fully conceptualize the problem and specify the model--let alone quantify it and come up with systematic and well-based research results and solutions.

Similarly, numerous environmental measures are enacted as discrete acts and means, without consideration of other alternatives and policies relating to the distribution of costs and benefits. As mentioned previously, environmental restraints are applied uniformly over the nation--as if everyone lived in the nation's large polluted cities. Also, it is not necessarily true that societal welfare functions will be maximized by absolute edicts requiring all persons to comply at their own cost to an environmental restraint. Often, the nature and pattern of the measure can give inequitable distributions of the costs and benefits.

In a preface paper to this conference, it was suggested that too much EPA work has had two steps; namely, a physical or biological impact study which found out that economic problems prevailed, followed by an economic study which showed that other social problems also prevailed. My recommendations to avoid these outcomes are for EPA to (1) drop the "aura" that it has only a two-year existence to organize as many as possible short-run studies--and devote more resources to long-run analyses which can better incorporate in single models the various physical, economical, and social facets; (2) devote more resources to policy studies which evaluate all of the tradeoffs in changing patterns of technology and resource use. In the latter case, alternative policy means to reach given environmental ends or objectives could be explored. We could then better indicate where and when subsidies and compensation should be used to alter these patterns and who should receive them, as compared to simple edicts or outright legislative prevention with which all must uniformly comply even though some gain while others sacrifice in income, resource values, and utility.

Professor North has well pointed out the complex setting within which fall actions to influence resource use and environmental impacts. However, I am optimistic and believe, as I have emphasized, that if we are serious, (1) we possess the means to organize the appropriate interdisciplinary teams; (2) the physical, biological, economical, and social variables can be adequately modeled--especially in a large number of cases if research projects and the view of EPA is turned more away from "do tomorrow the research we wanted yesterday" to longer term analyses; and (3) alternative policy means can be used appropriately and effectively in overcoming the problems of externalities that characterize environmental concerns.

Finally, it is possible that EPA should greatly alter its approach to research which has a focus on negative impacts and on restraining technologies and resource uses which give rise to them. The altered approach would be a more positive long-term one of catalyzing research to obviate the need for technologies and resource uses that pollute the environment. EPA would become less a "hand slapper," through legislated restraints of producer and resource owners, and more a leader to new technologies that possess fewer negative externalities and environmental impacts.

An example policy could be directed to feed grain production. Under economic growth, declining real cost of capital and subsequently more specialized farms have concentrated the production of food commodities and increased both the use of industrial inputs and the emission of products which are transported to streams (e.g., sediment, nitrate, animal wastes) as pollutants. Rather than purely a negative legislative approach, EPA could catalyze identification and assessment of the 264 million acres of Class I and II land (about 40 percent of land now cropped) which is not currently cropped and if used, could lessen the concentration of production. It could catalyze research on the feeding of carbon dioxide to plants so that greater yields per acre would allow more land to be substituted for chemical and pesticide inputs. It could catalyze research on symbolic nitrogen fixation and pest resistance of the major feed crops so that they could be grown over a wider area and be less dependent on large doses of nitrogen and insecticides. This more positive approach would require EPA to look upon itself less as a short-run "watch dog" and more as a positive institution reacting in a long-run cooperative manner with our well-established and long-existing public institutions, such as the land grant universities and other federal research organizations.

RESEARCH NEEDS

THIRD VIEWPOINT

RESEARCH IN AN ACCELERATING HUMAN ENVIRONMENT: THE PROBLEM IN OUTLINE

Ralph C. d'Arge

> "The hunter is camped on a great plain with a small fire providing a flickering light and intermittent warmth. Tiny wisps of smoke ascend into a vast, clear night sky. Tomorrow the hunter will move, leaving behind ashes, food scraps, and his own excreta. After ten steps these are lost from sight and smell, probably forever. With them he leaves too his brief speculation about sky and earth, brought on by the loneliness of night, and he peers toward the horizon in search of prey.
>
> The Administrator of the World Environmental Control Authority sits at his desk. Along one wall of the huge room are real-time displays, processed by computer from satellite data, of developing atmospheric and ocean patterns, as well as flow and quality of the world's great river systems.... Observing a dangerous red glow in the eastern Mediterranean, the Administrator dials sub-control station Athens and orders a step-up of removal by the liquid residuals handling plants there. Over northern Europe, the brown smudge of a projected air quality violation appears and sub-control station Essen is ordered to take the Ruhr area off sludge incineration for 24 hours."
>
> Kneese, Ayres, d'Arge[1]*
> (1970)

To quote one's own coauthored writings as a starting point for serious discussion is perhaps highly presumptuous, but may be an effective device for summarizing quikcly a particular viewpoint of the future. I obviously believe that environmental issues will become so overwhelming as to ultimately require international control and problem solving.

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*Footnotes are listed at the end of this paper.

During the past few decades, we have observed extremely rapid growth in: technology and technological complexity, per capita income, energy use, exotic chemicals, waste flows, environmental disamenities, environmentally related health problems, and bureaucratic structures to "solve" these problems. And I suspect such growth will continue unmitigated at least to the start of the next century. This suggests that certain types of environmental problems may begin to dominate our concerns. To be simplistic, let me taxonomically classify the types of environmental problems by the following ground divisions: (1) extent of impacts, (2) timing of impacts.

A quick glance at Figure 1 should indicate the direction toward which I believe we are moving. In terms of environmental problems, a specific new class seems to be emerging. This class can perhaps be typified as having the following characteristics:

> The problems are of long duration and may or may not be technically and/or economically irreversible.

A current example of a problem with the above characteristics is the emission of fluorocarbons 11 and 12 into the atmosphere. At current (1972) emission rates it is estimated that the global decrease in O_3 will not reach 5 percent before 2064 and the final effect on skin cancer incidence more than a generation beyond that.[2] Consequently, economic-environmental tradeoffs are over a span of at least 100 years. Can conventional benefit-cost analysis come to grips with this highly uncertain intergenerational choice? I think not, since a loss of our current GNP ($1 trillion plus) in 100 years at 6.125 percent[3] would be currently valued at less than $3 billion, less than the current gross product of the Libyan Arab Republic. Likewise, a loss of life at the fictional "public" value of $250,000 would be worth less than $600.

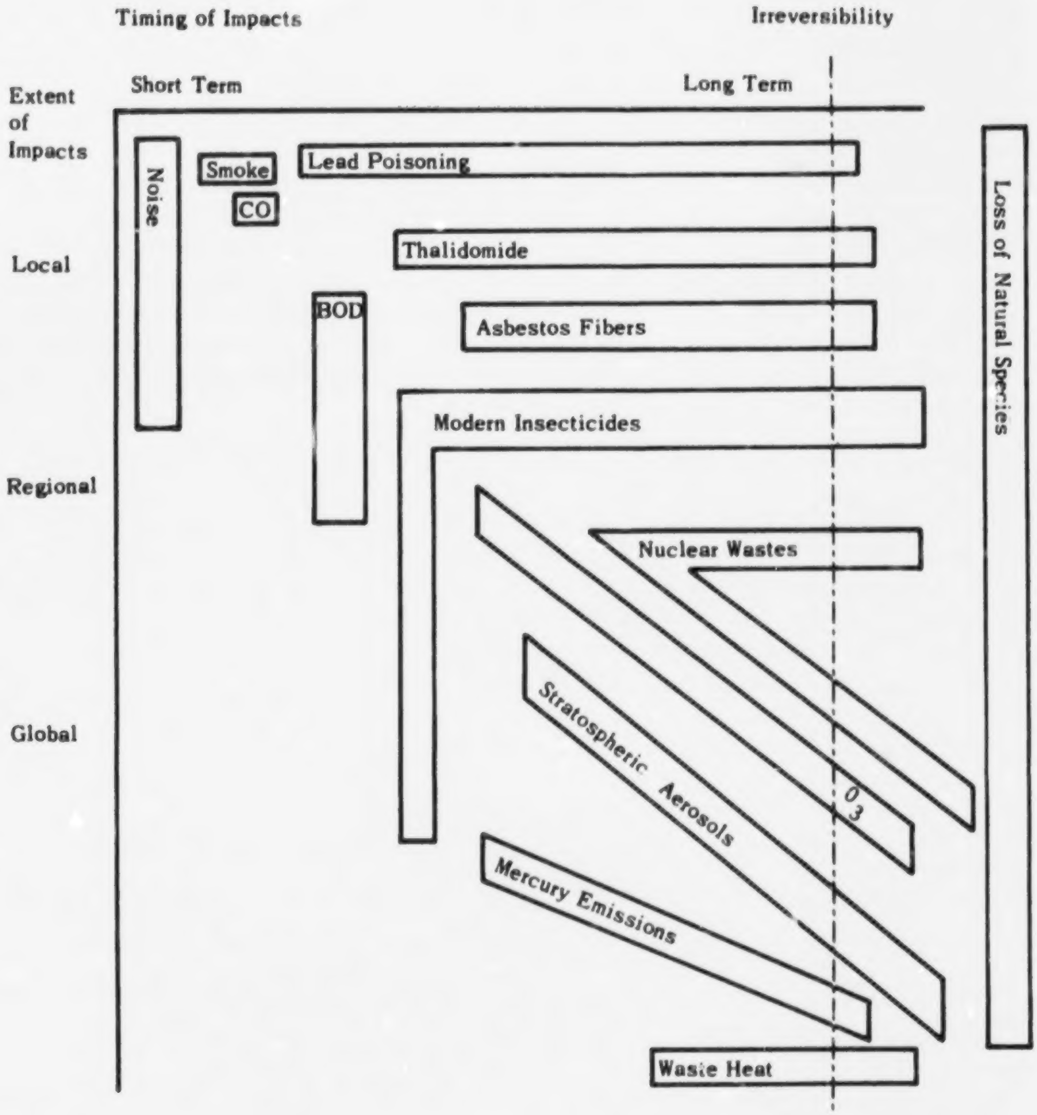


FIGURE 1. EXTENT AND TIMING OF ENVIRONMENTAL IMPACTS

A second striking example of the timing of impacts problem is the storage of nuclear wastes, thereby potentially endowing future generations with both the responsibility and risk. Kneese has typified the nuclear waste storage problem as a "Faustian Bargain."[4] To quote him at length:

> "It is my belief that benefit-cost analysis cannot answer the most important policy questions associated with the desirability of developing a large-scale, fission-based economy. To expect it to do so is to ask it to bear a burden it cannot sustain. This is so because these questions are of a deep ethical character. Benefit-cost analyses certainly cannot solve such questions and may well obscure them.
>
> These questions have to do with whether society should strike the Faustian bargain with atomic scientists and engineers described by Alvin M. Weinberg in Science. If so unforgiving a technology as large-scale nuclear fission production is adopted, it will impose a burden of continuous monitoring and sophisticated management of a dangerous material, essentially forever. The penalty of not bearing this burden may be unparalleled disaster. This irreversible burden would be imposed even if nuclear fission were to be used only for a few decades, a mere instant in the pertinent time scales. . . ."

Other examples of intergenerational environmental tradeoffs are plentiful. What is important ethically on such "timing" problems is the absolute inability of future generations to actively participate in policy decisions. While the environmental problems themselves may be reversible in the future, the decision is not once made. One special case of the long-term timing of impacts is where, for the foreseeable future, once an impact has occurred it is forever irreversible. That is, it will be impossible in the future to technically, economically, or socially return to a previously attained or natural environmental state. Irreversibility is defined differently here than commonly used in the physical sciences. Irreversibility in economics is often defined as being a new state where "there are no technical means of restoring the original character" of the state.[5] Draining of the Everglades, construction of Glen Canyon Dam, and the elimination of various natural species are often cited examples. Economists have argued that the possibility of time irreversibility of an environmental state requires the inclusion of new nonmarket values for the extra loss inherent in making an irreversible decision.[6] Whether such values can be measured for current generations is now in the pretesting stage, but it should be obvious that they cannot be measured for future generations.

It is clear that environmental issues with irreversible aspects have been growing rapidly in the recent past and there is no reason to suspect an amelioration in growth in decades to come.[7] What is of extreme importance is a decision methodology capable of at least partially accounting for actual or probable irreversible states.[8] Conventional decision analyses appear not to be sensitive to the unique attributes of long-term and potentially irreversible outcomes. We next turn to another attribute of the new class of environmental problems cited earlier.

> The environmental problems have suspected outcomes, but these are only vaguely understood and may never be.

Here perhaps is the heart of the difficulty in managing complex ecosystems. There may be a large number (at least as many as active scientists or advocates) of potential and feasible outcomes of a partcular environmental decision. None are adequately quantifiable without being substantially simplified and thereby reduced to a mechanistic and sometimes arbitrary prediction(s). This is, in my opinion, the basic problem of the "holistic" approach adopted by many environmental practitioners. To quote one obviously optimistic advocate:

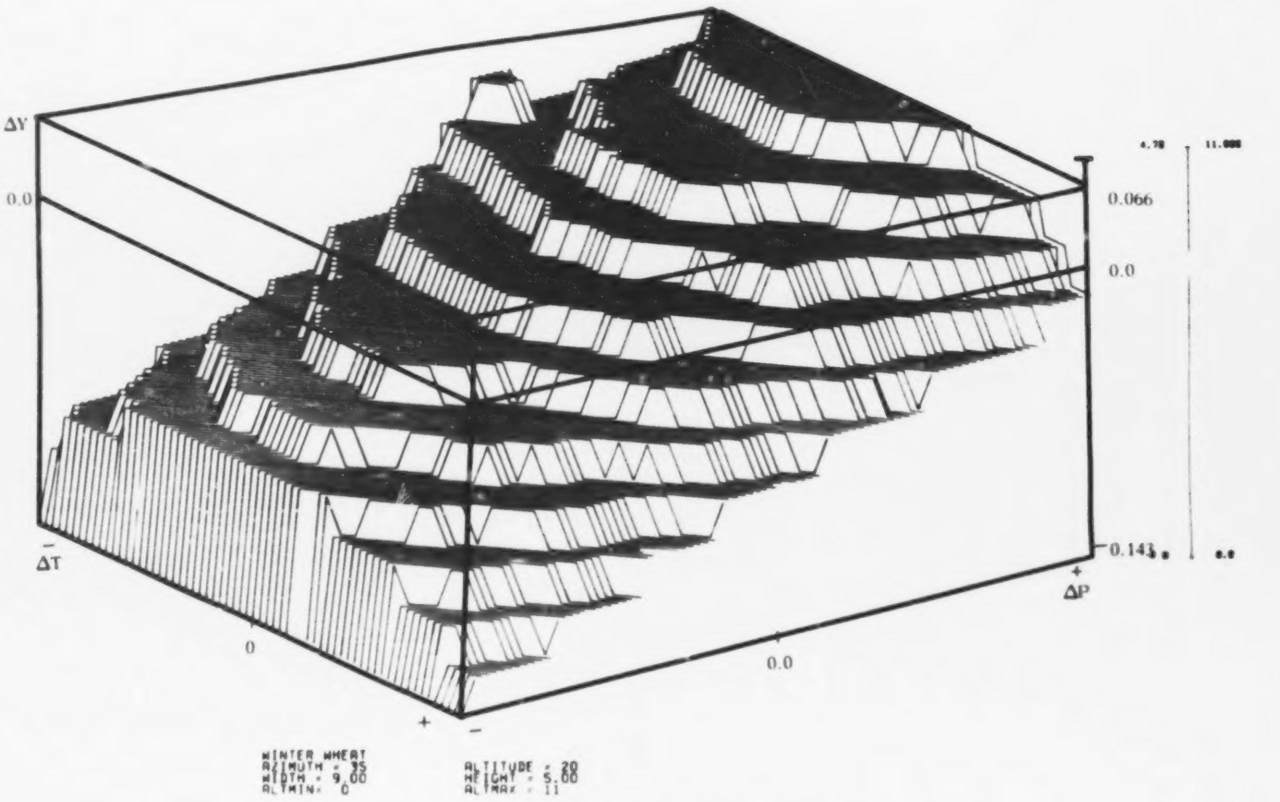
> "The President charged EPA to take a holistic approach to the environment, to view it not as an isolated series of events or pollution situations but rather, as an entity in

> which disciplines overlap and all segments are interrelated and interwoven. This "systems approach" rejects as simplistic the notion that we can protect the environment or enhance the quality of life by stacking a series of separate airtight Washington-based programs on top of one another."[9]

Thus emerges a recognition that "everything depends on everything else" and "complete modeling" will provide all of the useful answers. What is not recognized is the basic uncertainty underlying most, if not all, cause and effect relationships or, more popularly, "transfer functions." Coupling basically unknown or only slightly tested relationships compounds the likelihood of pronounced errors in establishing impacts or the range of policy choices.

As an example, if stratospheric flight through aerosol loadings reduces global average temperatures by say 0.5°C, policymakers would like to know what impacts this will have on world wheat production by region, prices, balance of trade and, most importantly, who will be hurt and who will gain. Given historical records (with few degrees of freedom), researchers can model wheat yields by region as related to climate and other factors (fertilizer use, available equipment, farm knowledge, frost-free days, soil type, terrain, elevation, insect infestations) and attempt to predict changes in yield by locale or region.

Figure 2 shows a very revealing diagram of how winter wheat in all regions of the USSR may vary with combinations of average temperature and precipitation changes.[10] Unfortunately, statistical data on yields and all other variables are imprecise. With given statistical and informational error, predictions are made, but the policymakers cannot interpret an average 1/10 bushel decrease (or increase) in yield for 42 major global regions. What they wish to know is at minimum dollars lost and dollars gained by country. In consequence, an econometric model of world wheat trade needs to be developed, again with historical data. The result is a set of statistical relationships based on $2.00



* Views 3–D Plot developed by and courtesy of Environmental Systems Research Institute, Redlands, California. Special thanks are extended to Eric F. Harnden and Ronald Eid of the Department of Earth Sciences, University of California, Riverside.

FIGURE 2. PROFILE OF YIELD CHANGES (ΔY) IN WINTER WHEAT FOR CHANGES IN TEMPERATURE (ΔT) AND PRECIPITATION (ΔP) U.S.S.R.

per bushel wheat with no substantial climatic variations (1958-71). Then along comes a substantial climatic variation causing an extreme regional shortage of wheat, with the price almost doubling. The models yield inaccurate predictions on two counts at least: yield is not calibrated for extreme variations and neither is price, yet extremes in both will occur almost simultaneously. The net effect is to almost nullify the value of modeling for policymakers. They do not want " surprise free" estimates but the range of possibilities and likelihood of them. But such a range or "window" of possibilities is always bounded by the historical past or the "reasoned" imagination. As you are well aware, the "bite the bullet" philosophy of indiscriminate policy groping has pervaded in such situations. Often there is an added dimension, one which Arrow identified as "learning by doing."[11] Basically, for environmental problems this amounts to testing on a small scale (small enough to avoid thresholds) the impacts of economic activity, be it introducing a new cosmetic or limited multiple use of the stratosphere. The question is how fast to allow emission or introduction without surpassing irreversible and/or costly thresholds. And a decision methodology for such questions is in need of development.

My central point is that it may pay society to approach certain environmental problems in terms of a "guinea pig" approach, where limited testing is undertaken but not to the point of subjecting large groups to substantial environmental risk. By recognizing that at least a part of man's technological future depends on taking some risk (and evaluating it beforehand), might we be able to have our cake and eat it too? That is, discovering new products that are both desirable and not very harmful to either present or future generations. The element of uncertainty as to long-term future impacts will always be looming and depend crucially on our understanding of both natural and perturbed ecosystems. But "learning by doing" appears to be a dominant strain in human nature and beyond recall.

A third characteristic of the emerging environmental problem is its extent by population, by geographical domain, and perhaps by cultural domain. Let me generalize this characteristic as follows:

> The extent of environmental problems, in geographic domain, is growing rapidly; and in the future problems with the commons will be global or, at minimum, multinational in scope.

About six years ago, rather facetiously, I suggested that if the world were a flat plain, Los Angeles grew by a factor of seven, and prevailing winds continued, Cambridge (Massachusetts) would become a recipient of Los Angeles' smog.[12] It received a long laugh but few serious comments by the economists in attendance. But perhaps Harvard is now not so sure.

With the advent of nuclear explosions and fallout, mercury, oscillation in fish species, continuous contrails, regionalized heat islands, multinational water pollution problems (i.e., Baltic, Mediterranean, Great Lakes, North Sea, and Colorado River), the extent of multinational environmental dependency has become apparent. With oceanic oil spills, crowding of air waves, potential rabies transmission across Europe, the recurrent flu epidemics constrained at Marseille and Genoa before spreading to the European continent and the Americas, the "Cousteau" ocean litter reports, and worldwide fluorocarbon pollution of the stratosphere, we have all become aware of potential "closeness." What is obvious is the degree of environmental dependence among nations even though traditional problems of trade discrimination and power are still prevalent.[13] The "global commons" will be with us an an international issue with or without the "oil Cartel." In order to provide a bench mark for studying rational decisionmaking in a world characterized by the class of environmental problems identified earlier, I should like to present a short parable.

Let us assume that there is a world environmental agency with a one-minded directorate that is suddenly confronted with the realization that they will not be able to sustain life endlessly on earth. They are irretrievably confronted with finite and given resources. Within their "spaceship earth" are stored enough provisions to sustain life for a period of time shorter than the communities' "normal" evolutionary life-span, even if they consume at minimal subsistence in terms of caloric intake. Clearly, if the communities' criterion of welfare is the singular objective of maximizing the length of existence, they collectively will not consume above the minimum subsistence level. Alternatively, they may be more or less myopic, depending on one's philosophy, and decide to consume at a faster rate, particularly if they evaluate an additional year of existence at near starvation levels to be of less value than an increment of present consumption. The rational committee would consume at a rate during each period of consumption such that they equated the marginal utility of a unit of consumption in that period with the foregone opportunity, in terms of utility, of consuming that unit in any future consumption period including the period following the one in which they run out of provisions. The price of this foregone opportunity will also include a positive shadow price for not being able to consume below a minimal subsistence level if such a level is constraining to their desired rate of consumption.

From this extremely naive model, we are able to make several inferences. First, if the committee has a positive finite rate of time preference they will consider consuming at a higher rate than minimal subsistence only if their evaluation of an additional time interval of survival is not infinite. Second, if their preferences and capacity are such that they exhibit diminishing marginal utility of consumption individually, they are likely to spread consumption over a longer time span than if they achieved bliss through an immediate orgy of satiation.

Next, let us revise our assumptions and introduce the idea that since the community resides in a sealed capsule, they must endure the effects of their own waste generation. The community is now confronted with the problem that higher immediate rates of consumption will mean a higher density of wastes to live with during future time intervals. To analyze the question of rational planning, let us stipulate the following assumptions: (1) the communities' preferences are such that they have individually and collectively diminishing marginal utility of consumption and increasing marginal disutility induced by expanding waste density; (2) there is some waste density or concentration that is lethal to the community and they are aware of this; (3) there is very little or no assimilation of wastes or recycling within the "spaceship earth"; (4) the community has totally enough provisions to last all normal lifetimes and this lifetime is a very large number such that their only binding constraint is their generation of wastes; (5) consumption and waste emissions are joint products, i.e., the principle of conservation of matter-energy is operative; and (6) the community is not decreasing in size and does not discount future consumption at a negative or too high a positive rate.[14] These assumptions lead to at least two alternative rules of rational decisionmaking, depending on what goal is to be achieved. Rule 1: If maximizing the length of existence is of primary concern, the community will immediately reduce consumption to the minimal subsistence level and remain there until decimation occurs. Rule 2: If continued existence is not of overriding importance, the community will immediately reduce consumption upon discovering the finite dimensions of the planet earth but increase it thereafter.

The logic underlying this proposition can be seen by describing the problem as one of campers entering a campground and planning to stay for some finite interval of time. The campers are confronted with the problem that if they consume their provisions and discard waste at a high rate initially they will have to suffer the "disutilities" of this waste during the remainder of their stay. However, if the campers consume at a low rate initially and build up consumption over time, they need not suffer too much from waste generated in early intervals and yet increasing consumption allows them to compensate for the increasing waste density. At some point they will depart following an orgy of consumption.[15] Whether this parable is plausible remains to be seen; but current "rational planning" is toward a "steady state" gradually in the long run, the exact opposite of the optimal path identified here which is to move to a "steady state" immediately, if at all.

Man is no longer a hunter within an infinite environment, but he may not have yet reached the pinnacle of despair where he must absolutely plan for each year of future existence analogous to a virtually bounded community. He has reached, in my opinion, a turning point--one that could be irreversible; and one that is dangerous for his future survival. Let us turn to the question of what he should do now. I would like to set forth several assumptions on the milieu shrouding the interactions between man and the natural environment as I perceive them.

First, and overwhelmingly, man will not understand in detail the interweaving patterns and forces within his own ecosystem. (Me may be able to discover parts and even at times the whole of a subsystem such as how a particular wasp ovideposits eggs into the stomach of the larval form of cotton leaf beetles.) Why? Because he can never observe all the interdependencies that exist. Laboratory experiments will never yield empirical estimates of immediate and simultaneously long-term interactions between thousands of species. The ecological system has been described as a "Rube Goldberg" world with an almost infinite set of causes and effects. We can only perceive what our minds (with the aid of digital computers) will allow us to conceive. And, being an economist, I would assert that diminishing returns to individual inputs occur, not only for men's minds, but also for digital computers. Thus, we will continually be faced with environmental uncertainties and substantive ones, for which little or no information exists. This will induce, in my opinion, the continued appearance of the following type of problem--an uncertain world with potential eco-catastrophies as a tradeoff with immediate but very costly actions to reduce this probability.

A fourth aspect involves man's conditioning to believe he resides in a cowboy economy where by definition positive incentives yield positive actions. But do they? Restrictive effluent charges may include firms to bribe administrators of control programs to look the other way or design devices to electronically "jam" monitoring devices.

The EPA's control strategy for vehicle emissions so far has emphasized new vehicle emissions standards but has left all technical decisions to achieve these standards to the manufacturer. The automobile manufacturers have decided to utilize and develop catalytic exhaust reactors with relatively low fixed costs but high operation costs rather than other devices of a thermal type with potentially high fixed costs but lower maintenance costs. Whether catalytic reactors will be more efficient is unclear now, but what is clear is that even if they were not, allowing automobile manufacturers to make this decision would lead to their adoption. The reason, of course, is that it is more costly for manufacturers to charge a higher price for their product directly than to pass on higher servicing charges to consumers. This would not happen in a purely competitive static market where all consumers had complete information prior to purchase nor would it happen if less indirect controls were adopted. Further, the decision to emphasize catalytic reactors had induced expenditure on this particular type of technology. Whether such expenditure is an efficient allocation of research funds is at least debatable, given current assessments of other possibilities including the external combustion engine. Finally, the choice of catalytic reactors requires the elimination of lead additives in gasoline with a higher "natural" octane rating will have to be produced. It has been hypothesized that such high octane gasolines without lead will cause greater emissions of olefins and other complex reactive hydrocarbons. Whether olefins or lead is the more harmful pollutant in urban environments is not at this time known, yet a decision for catalytic reactors has already been adopted. The indirect control strategy of new automobile emission standards contains dynamic and uncertain elements which, if left to the choice of private and profit-seeking manufacturers, may lead to new externalities arising from the health effects of olefins or unexpected vehicle operating costs.

What this boils down to is the inability of society to adequately predict and thereby regulate individual behavior via the traditional "tools" such as taxes, standards, or subsidies, since behavior is generally unpredictable and has not been adequately modeled. Unimagined responses may predominate unless intensive testing of behavioral "transfer functions" is undertaken.

A fifth major issue is the observed lack of ability of current environmental institutions to respond to the class of problems identified earlier. This is in part due to the internal-external incentive system which aggressively supports short-term solutions of short-term issues with little or no thought given to the long-term implications of either the issue or solution. Further, the incentive and administrative structures may not even permit active coordination and research on this class of problems. Research is needed on alternative environmental institutional designs and internal incentive systems and on the optimal relationships among institutions at different levels of the administrative or regulatory hierarchy.

Can these five rather dominating aspects of the new class of environmental problems be solved? I believe so, but not by utilizing (except in particular circumstances) either traditional tools of regulation or traditional institutional structures for implementation. The EPA currently is operated as a reactive agency. A particular problem emerges and the EPA studies it and then institutes some form of regulatory action. But at least some damage has occurred before regulatory action is implemented. And in those cases where pervasive environmental consequences emerge, such an agency is equivalent to a salesman inquiring whether the malaria patient would like to purchase a mosquito net.

Let us briefly review the subset of environmental problems taxonomically identified earlier: they are long term in the sense that choices now involve effects on multiple future generations; they may involve irreversible decisions now; they are vaguely understood as to all possible ramifications and may involve the possibility that to learn about impacts, trials must be attempted, and finally; this environmental problem subset tends to be more than national in impact and likely to be amorphously global. Can we design a decision methodology that is publicly acceptable and yet socially productive? Optimistically I believe so but only with a well-conceived research design. The following list for EPA of general research needs may be useful as a preliminary design:

- EPA's research strategy in the past has been one of spending dollars on every conceivable problem. While perhaps such an approach assures "safety first" when all environmental problems have an equal probability of being catastrophes, it is a bit naive today, even given current uncertainties. The type of problems identified earlier seem overwhelmingly important. Let the lawyers and a few economists haggle over the more mundane ones.
- Concentrate research funds on environmental issues where "back of the envelope" policy decisions are unlikely to be valid and where interdependencies and/or long range impacts

are pervasive. Enough has been spent on automotive emissions controls and mundane water quality models.

- Develop approaches to weigh consistently intergenerational costs, benefits, risks, and uncertainties.
- Initiate a research program on the problem of environmental irreversibility, including irreversible losses of flexibility, resiliency, stability, and resources.
- Emphasize the development of simple, straightforward, generalizable policy models that are comprehensible in structure and variables to policymakers, and hopefully to the general public.
- Conduct research in an experimental mode on new approaches to regulation and human behavioral transfer functions. That is, on a limited scale, test alternative control strategies as to their behavioral impact.
- Develop an active research program on alternative types of instiutional structures for organizations involved in monitoring, regulation, and policymaking for the environment.

Footnotes

1. A. V. Kneese, R. U. Ayres, and R. C. d'Arge, *Economics and the Environment: A Materials Balance Approach* (Johns Hopkins Press: Baltimore, 1970).

2. Federal Council for Science and Technology, CEQ, *Fluorocarbons and the Environment*, Report of Federal Task Force on Inadvertent Modification of the Stratosphere (IMOS), p. 28 (June 1975).

3. Current rate of discount adopted by the U.S. Water Resources Council for benefit-cost evaluation of water-related projects. The Nuclear Regulatory Commission proposes the use of 10 percent for evaluation of privately financed environmental projects. A 10 percent rate of discount would reduce the present value of the $1 trillion in 100 years to less than $80 million and the "value of a human life" to less than $20.00 currently. See *Environmental Report to Accompany Application for Facility License Amendment for Extension of Operation with Once-Through Cooling for Indian Point Unit No. 2*, Consolidated Edison, for the U.S. NRC, Source 8.4, Appendix B (June 1975).

4. A. V. Kneese, "Benefit-Cost Analysis and Unscheduled Events in the Nuclear Fuel Cycle," *Resources* No. 44, Resource for the Future, Inc., (September 1973).

5. Anthony C. Fisher and John V. Krutilla, "Valuing Long-Run Ecological Consequences and Irreversibilities," in H. M. Peskin and E. P. Seskin, editors, *Cost Benefit Analysis and Water Pollution Policy*, the Urban Institute: Washington, D.C. (1975).

6. The various nonmarket values have been called "option value," "existence value," etc. For an exhaustive discussion of "option value" and preliminary empirical tests, see J. V. Krutilla and A. C. Fisher, *The Economics of Natural Environment: Studies in the Valuation of Commodity and Amenity Resources* (Johns Hopkins Press, Baltimore, 1975).

7. In recent years, more than 5,000 new toxic substances have been introduced in the United States per year with little or no understanding of their long-term impacts on ecosystems. The recent work of Ames and Commoner in designing tests for probable carcinogenecity is a step in the right direction but appears small compared to the ongoing capacity for development of new, exotic chemicals. *The Toxic Substances List*, 1974 edition, U.S. Department of Health, Education

and Welfare, Publication No. (NIOSH) 74-135, Rockville, Maryland (June 1974). The proposed Toxic Substances Control Act, however, may through "regulatory lag" reduce the rate of growth in "potential" chemical irreversibilities.

8. Even if we abstract from the problem of future generations values and losses or now to weight them against the present, traditional decision approaches may be faulty. Consider the following problem (abstracted and simplified from recent studies of pollution by stratospheric flight):

		Temperature Change	Probability	Cost (Billions U.S. $)
Decision	Unregulated flight	-1c°	.001	$400
		0	.740	0
		+.25c°	.259	-2
	Regulated flight	<±.05c°	1.0	<.100

Given the expected value criterion unregulated flight yields expected costs of .001 ($400) + .740 (0) + .259 (-$2.0) = $.118 billion or a net expected benefit! But should society take a 1/1000 chance of losing 1/2 the U.S. GNP? I think not if the problem can be resolved for less than 1/10,000 of GNP or less than a 20 percent increase in ticket prices. For detailed cost and benefit estimates, see R. d'Arge, et al, Economic and Social Measures of Biologic and Climatic Change, U.S. Department of Transportation, GPO (1975). For subjective probabilities of climatic change, see Climatic Impacts of Stratospheric Flight, National Academy of Sciences, Washington, D.C. (1975).

9. Gary H. Baise, "Regionalism in EPA: From Programs to Policy" in L. E. Coate-P. A. Bonner, editors, Regional Environmental Management: Selected Proceedings of the National Conference (John Wiley and Sons, New York, 1975).

10. The analyses were undertaken under my direction at the University of California, Riverside, by David Mayo and Jane McMillan. For a complete description, see D. Mayo and J. McMillan, "An Empirical Analysis of the Effects of Changes in Climate on USSR Wheat Yields," Draft prepared for U.S. Department of Transportation, UCR (June 1975).

11. K. J. Arrow, "Economic Implications of Learning by Doing," Review of Economic Studies, pages 155-173 (June 1962).

12. R. d'Arge, "Economic Growth and the Natural Environment," in A. V. Kneese-B. T. Bower, editors, Environmental Quality Analysis (Johns Hopkins Press, Baltimore, 1971).

13. While almost everyone would agree energy cost is now a dominant issue, it depends fragilely on a "cartel, and as economists have recognized, cartels tend to be short-lived because it pays for at least one member to undercut the others provided the remainder remain as a cartel. The optimum is to be the noncooperative member of a cartel, realizing gains from the restricted price, yet selling slightly below in large quantities. It is generally the economists assumption (unproved) that such cartels are inherently unstable unless side-payments can be made among members.

14. If the community discounts the future, this implies it values consumption or death at less in future years than the present, which appears logical if the community has no future generations. If it does, then a case can be made for valuing future generations equal with the present, in terms of happiness, utility, or loss due to premature death. If such a case can be made, then a zero discount rate is implied, i.e., one that weights benefits and costs equally for all generations. For discussions of these and other issues, see W. Schulze, "Social Welfare Functions for the Future," American Economist, pages 70-81 (Spring 1974).

15. Have you ever observed a group of campers having a big party on the first night of their visit to a beautiful alpine lake?

REVIEW OF THE PAPER BY R. C. D'ARGE

W. E. Cooper

The paper focuses on one of the most important classes of environmental problems concerning ecologists. This involves the regulation of residuals emitted into the biosphere from agricultural, industrial, and domestic material cycles which are toxic, long lasting, broad spectrum in effect, and mobile due to their solubility in water. The author correctly characterizes the future trends in resource utilization as one of increasing intensity and distribution of emissions of toxic substances. Toxic increases will occur particularly as synthetic compounds are developed and produced in a frantic effort to escape the ultimate constraints of material limitations and the thermodynamic implications of dependence on closed energetic systems. He discusses the dominant systemic characteristics in terms of future research, policy development, and management strategies given technical uncertainties, time lags in the response of the ecological systems, and irreversible damage functions resulting from this class of ecological insults.

My response will focus on the critical assumptions that must be tested and the new technologies that must be researched if d'Arges' paradigm is to be operationalized in the real world.

Control versus Design

The initial decision must involve the choice between basic strategies of protecting the public from the results of residual emissions. One alternative is to develop more and more sophisticated control devices oriented towards regulating the flows of residuals at the points of discharge. Such a system can be implemented through the market system

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utilizing economic incentives and/or disincentives as presented in d'Arges' paper or by constraints codified as performance criteria (emission standards) or by liabilities associated with legal statutes prohibiting "unreasonable pollution." Much literature and experience is available on all three strategies. If one hopes to rely on the control approach given the cost of being wrong, it must be designed to perform flawlessly. Given the specificity and dynamic nature of the ecological system, the prices and standards must be regionally specific and equally as dynamic as the object to be controlled. There are a number of formal characteristics of the control structure that must be researched and developed if this level of performance is to be expected. These include:

- Observability--It is critical that sufficient parameters can be adequately monitored. In a control system, what cannot be modeled must be monitored. This monitoring must approximate on-line (continuous information flows). Currently, many of the sensors and the information networks do not exist.
- Integration--The information must be integrated without significant distortion or deletion. The "biological" systems integrate with physiological weights (degree days) while the "human" system has a series of social weights. Little is known about when and how to determine and then synthesize these functions.
- Time lags--All biological systems are characterized with time lags in responses to all kinds of stimuli. Most human institutions are similarly structured. Because of this, one can forget the myth of the "Balance of Nature." These systems will not converge to equilibria. The control problem is one of managing a continuously unstable system. The instabilities are directly related to the nature and distribution of the time coefficients of the critical processes. These involve the dynamics of energy, materials, and information. Not even the most simplistic analyses have been completed in this area. We are trying to design a control structure without even having the basic system characteristics as design constraints. This is poor engineering.
- Energy Costs--One of the limitations to this approach will be the energy costs required to obtain adequate controls. With high throughputs of materials (sewage disposal, agriculture,

> and the like) and relatively homogeneous (simple) systems, the benefits will probably justify the energy costs of construction and maintenance of the control system. As the system is more highly dispersed and/or the ecological-industrial couplings more heterogeneous, the energy costs per unit control must increase. Little if any research has been directed toward determining when this control approach is energetically feasible.

The alternative option is to assume that the control structures will not be adequately designed and maintained to prevent individual or institutional mistakes. If the weakest link in the system is an individual, then one must design the system to be "idiot proof." We have just buried about 23,000 dairy cattle in Michigan because of PBB contamination of the agricultural food chain as the result of a human error at a routinized but critical node in the system. To design a system to be idiot proof, one must utilize ecologically sound criteria so that the environment is biologically tough and spatially buffered enough to assimilate the results of a human error without experiencing irreversible effects. These criteria include:

- Spatial Patchiness--Ecological systems are exceedingly tough because they are composed of a redundant pattern of semiautonomous biological units (communities). In general, human activities minimize this critical design feature. What are the economic and energetic tradeoffs between maintaining environmental heterogenity and increasing the costs of external control strategies associated with homogeneous biological landscapes? Little research on this has been completed.

- Open Systems--Ecological systems are resilient predominately because they are open (at least to information). Recolonization following local extermination is a major factor in maintaining bounded instabilities. Utilizing regional zoning to maintain the integrity of ecological enclaves is a critical design option to increasingly costly controls. This is specifically true with lake, stream, and estuarine ecosystems. Again, little has been done to determine required size, spacing, environment, and so forth. Ecological engineering is a future option that must be researched. The alternative is an electronic engineering approach that is capital intensive and energetically costly.

- Regionally Specific--Local ecosystems have significantly different properties and capabilities. If the object of environmental programs is to protect the integrity of the "natural ecosystem," then the control criteria must be ecosystem specific. More intensive care must be taken with fragile systems than with resilient systems. Exactly how one translates fragility into regional emission standards, land-use patterns, and capital investment strategies is only poorly understood.

Other Related Issues

There are a number of other issues related to points presented in Ralph d'Arges' paper. I will discuss these briefly in a somewhat random order. The list is not inclusive, but will more than keep EPA busy if they attempt to concentrate on all of them at once.

Distributive Source--Considerable work has been completed by economists and engineers on the control and design options of dealing with point source emissions. The problems of dealing with distributive sources is far more ecologically important and technically difficult. In Michigan, we have buried over 4 million salmon because of PCBs in the fish. No feasible substitutes are currently available for use in transformers and capacitors, and no one is yet capable of preventing dispersed and multiple inputs of PCB into the biosphere. User charges and discharge standards do not do a bit of good to the fish in Lake Michigan. Considerable effort should be spent in identifying and solving problems associated with synthetic compounds with these generic characteristics. With the approximately 500,000 synthetic compounds currently produced and discharged, I am sure that similar "horror stories" are carefully nested within the pot of social ignorance.

Management by Objectives--Ecologists have considerable flexibility in the design of biological landscapes. If you want Lake Erie to produce animal protein, you could manage it concurrently as a tertiary treatment plant and as a carp farm and most probably maximize its "throughput" of materials and energy. If society wants a "Walleye Pike" lake and gets one, there is no problem. If they want a "Carp Pond" and get one, again no problem. But, if they want Walleye Pike and get Carp, society calls it a polluted lake. As far as I can tell, we have NO management objectives towards which we can work with both control and design strategies. Given this, we most probably will have to assume multivariate objectives and attempt to minimize unhappiness. Nobody will really win. How can EPA policies suboptimize distributive systems that are nonlinear, hierarchically organized, with time lags when society has a large number of object functions?

Perturbation Experiments--Considerable importance is attributed to the concept of irreversibility. At the population level of ecological organization, extinctions of species is an obvious irreversibility. The majority of social concern over "threat to the environment," however, involves community level ecological responses. At this level, species populations are expendable. Extinction is one of the more deterministic events in ecology, given a long enough time horizon. What is uncertain is knowing the limits to the community's ability to "adequately recover" from external perturbations. Community ecology is only in an embryonic stage of development. Our ability to model community dynamics and anticipate biological significance is extremely limited. Empirical experimentation must be utilized to gain immediate insight into the array of response behaviors for various types of communities. You systematically kick them and see which way they jump. Determinations of the frequency, intensity, and distribution of external insults that are critical at various seasons in the year must be obtained. Good, old field experimentation is probably the best way to start.

Open Loop versus Closed Loop Controls--A basic problem arises when one considers controls over a system where public and private components are coupled. The environment is generally considered public and the major emphasis is given to the responsbilities of stewardship. The private sector deals with a subset of resources that enter the market due to their societal utility. This component emphasizes the rights of ownership. When coupled together, the private sector more often operates around the benefit/cost of being right, while the public sector makes decisions around the risk/cost of being wrong. There is no way that the Michigan Allied Chemical Company or the Michigan Farm Bureau can compensate the people of Michigan for the damages resulting from their errors with PBBs. Neither can Reserve Mining be held accountable, if the asbestos from their taconite tailings entering Lake Superior is causing intestinal cancer. Control policies that internalize the liabilities of being wrong in necessary and sufficient forms must be developed if the control approach is to function satisfactorily.

The above are a subset of issues resulting from the paper presented by Ralph d'Arge. The selection reflects my personal priorities of needed research that should be initiated soon. Many of these are generic defaults in our current institutional approaches to research and management and, therefore, are common to constellations of perceived problems such as energy, food production, land use, nuclear waste, and so forth. If EPA is really a regulatory agency, and if their goal is to manage the couplings between industrialized societies and their ecological environment, then the research priorities must be cast in a testable and useful fashion compatible with a general system paradigm of control and design.

RESEARCH NEEDS

FOURTH VIEWPOINT

RESEARCH FOR REGULATORS

George M. Woodwell
Marine Biological Laboratory
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Georges Banks is a large shoal area off southern New England. It is one of the world's richest fishing grounds and an area of spawning and nurture for the fisheries of the northwestern Atlantic. Georges Banks is also one of two or three of the most promising sites for oil exploration on the eastern seaboard. Almost no one believes that oil wells in the area will enhance the fisheries; some believe the development will be disastrous.

The controversy surrounding the prospect of oil developments on fishing grounds is a good example for us because of its contrasts. The industrial machine, starving for oil, monstrous, wealthy, politically powerful, is driven by soaring oil prices to compete on the fishing grounds with a hunting-and-gathering culture that harvests poorly managed natural ecocystems that are obviously being rapidly degraded by over-harvest and other factors quite apart from oil. When measured by our economic system, the fisheries have at present small value compared to the value of the oil. The oil interests, if allowed, could buy the fishery or any part of it they damaged.

The situation seems anomalous: with starvation endemic in larger and larger areas of the world, how can the value of industrialization so far exceed the value of food that the search for oil can displace fisheries, a potentially renewable source of protein and virtually the only method we have of harvesting food from two-thirds of the surface of the earth.

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There are many reasons and one can pick and choose. One reason is simply that those who are hungry are hungry because they are poor. They are not participants in international commerce in food or almost anything else. Their needs are not a factor in the controversy except as governments choose to make them so. The rich, those who have energy, are not yet short of food and the economic system has not swung to put these values in balance. It may never do so; such is the complex of forces in the economics of resources.

If our perspective is of the world as a whole, the world needs the fishery more than it needs the oil. If our perspective is limited to the national level, the competition among industrial nations may demand the oil now in support of our own position in politics and commerce. Because we have enough food at the moment, we can lose the fishery if need be.

If we ignore one perfectly sound stance, despair, there are two polar schools among those who explore such issues. Certain technologists, politicians, economists, and others believe still in the salvation of a technological growth that feeds economic growth indefinitely. Energy is the key; with cheap energy we can make whatever other resource we require, potentially including food. On this basis a no-holds-barred approach to energy is justified. The fishery is a trifling cost. No research is required and no regulation appropriate.

Others argue with equal force that technology has made no new resource; it has simply allowed the transformation and transport of other resources around the earth to forms and places convenient for man. They would not abandon technology; far from it, but they would assert that the benefits of industrial growth, at least in the present form of industry, are finite and are now outweighed by costs not yet properly tallied. Industry will not follow this path, of course. It falls to the regulators--to government.

The arithmetic of exponential growth, growth in population, growth in demand for food and other resources; coupled with recognition of finite oil reserves, limited agricultural production, the effects of the accumulation of CO_2 in the atmosphere, the effects of released of sulfate and nitrates into air, the leveling of fisheries yields, the limitations of debt in cities, the problems of sewage treatment, nuclear waste storage, limited fresh water supplies, the growth of welfare and many other new constraints all assure not only the series of changes in our lives that we see in motion now but soaring pressures on all resources. Almost no one will accept an unbridled reliance on growth and technology these days.

The confrontation between the industrial system with its emphasis on short-term profits and those segments of human welfare that depend on biotic resources, the competition we see between oil and fisheries in the northwestern Atlantic, will become steadily more commom and more acute. This does not address the competition within the fishery among those who would harvest fish; that competition too, is soaring. More than that, the pressures cannot be isolated, geographically or politically. Air and oceans are international resources. How must their use be regulated? What is fair? What research will best support that regulation? How can we best "restore and enhance the quality" of environment as the Water Pollution Control Act Amendments of 1972 command?

There seems to be very little choice. The pattern we have at the moment is largely based on the false assumption that resources are large in proportion to the pressures we place on them and that this relationship will hold indefinitely. A corollary has been the concept of an "assimilative capacity," presumably a finite capacity for absorbing a waste, a series of wastes, or an effect.

An assimilative capacity can presumably be divided among different users, and redivided as potential users increase in numbers. It is elusive, however. A stream may have the capacity for oxidizing organic matter at a certain rate and be assigned an assimilative capacity. But the reality of such an assimilative capacity for organic matter does not automatically extend to other substances introduced with the organic matter. We believe that there is no assimilative capacity for DDT and other toxic chemicals. The concept of assimilative capacity is not merely vague but illusory. It encourages a pattern of use of water and air that virtually assures progressive degradation by encouraging the assumption that pollution is acceptable. The burden of regulation, which is government's, becomes virtually impossible: the criteria are necessarily vague, the sources of pollutants may be large and numerous, the political and economic pressures to allow various pollutions, continuous. Small wonder that the system fails; it is designed to fail.

Added to this is the difficulty of regulating it. There is a perfectly reasonable propensity for a species-by-species and toxin-by-toxin approach using classical toxicological techniques. The array of species, the problems of culturing them, the array of toxins, the possibility of interactions, the remoteness of laboratory from nature all make such approaches virtually impossible when pressures to exploit are high.

The alternative is clear. In a world condemned to soaring populations and more rapidly soaring demands on resources, the basic pattern in use of environment must be the closed system: countries that do not infringe on one another by fouling air or water held in common; cities that recirculate their water, nutrients, metals, and certain fibers; industries that accept responsibility for their wastes as they do their saleable products; agriculture that does not poison waterways with pesticides or fertilizers; and power plants that do not infringe on biotic resources with extraordinary demands for cooling waters. This pattern of use of the surface of the earth is the cost of intensive use. The basic principle is no pollution; not pollution within limits.

You will immediately think of exceptions: How can we burn fossil fuels without releasing CO_2? The answer of course is that we cannot, but it is conceivable that the amount of CO_2 emitted in total should be a matter of public interest and, possibly, controlled. Certainly the amount in the atmosphere, its patterns of circulation, its fate, and its effects through the next years should be known. We can make clear decisions to allow normal geochemical fluxes to be modified within certain limits, if we choose. But the central principle remains the preservation of the earth's basic chemical and biotic patterns.

All of this is set forth to establish the background for discussing the research that is appropriate for the EPA in support of its regulatory activities. The early steps in the transition toward closed systems have been written into the law. The policy statement of the Water Pollution Control Act Amendments of 1972 set that forth boldly and the law itself, complex as it is, provides details of the transition. No one expects a transition to closed systems to occur immediately. Indeed, the transition will probably not occur until its feasibility has been demonstrated. It is a challenge for the EPA to provide the background necessary in research.

The research program in support of this transition is obviously going to be complex, developed over a period of years, and include much of the work already under way in support of current patterns of regulation. I shall mention three segments that should be added now as a part of the program that must emerge: first, a continuing analysis of the world carbon budget; second, a new program designed to discover the details of biotic impoverishment and how to recognize the earliest stages of it; and third, new ventures in the recirculation of water and nutrients in sewage. I have chosen these not only because they are important topics, but because they are examples of types of research in which the EPA must now become expert. I can do no more than outline these topics superficially.

The basic resource in support of human activities is carbon fixed in photosynthesis and made available in various forms to man. There is abundant evidence that the world carbon budget is being affected grossly by human activities. The major evidence is through the accumulation of carbon dioxide in air. The concentration is now increasing at the rate of about 1.5 parts per million per year and the rate seems to be increasing. The cause of the increase is generally believed to be the combustion of fossil fuels but the destruction of forests and the oxidation of humus are probably also contributory causes. Despite the fact that two-thirds of the surface of the earth is water, two-thirds of the total photosynthesis on earth occurs on land and most of that is attributable to forests. There is good reason to believe that the total amount of photosynthesis on earth is diminishing, although there is at present no detailed analysis of this problem.

To the extent that photosynthesis is a measure of the functioning of the biosphere, a decline in worldwide photosynthesis would be a serious matter. There is moreover the possibility that increasing amounts of CO_2 in the atmosphere will lead to temperature and climatic changes that can occur suddenly and change agricultural productivity over large areas. The topic is of obvious importance to governments and it would seem that the EPA would do well to develop primary competence in it, either through research in its own laboratories or through research under contract in other places.

The second topic emerges from a detailed consideration of the first. If we accept the principle of ecology that the qualities of the biosphere essential for support of man are maintained by the matrix of late successional ecosystems that have dominated the earth throughout all of human history, then we recognize that the preservation of this matrix is a major challenge in the regulation of human activities. Chronic or long-lasting changes in the physical or chemical environment bring changes in the biotic structure of this matrix of natural systems. The changes themselves are an index of the effects of man. Just as changes in bird populations gave us clues that persistent pesticides were accumulating in places they should not be, so changes in the incidence of disease in forests, changes in the composition of phytoplankton communities, changes in the spectrum of zooplankton and fish in bays give us an indication that the physics or chemistry of environment has been modified.

With experience we learn that the patterns of change are consistent among many types of disturbance in any community. The patterns of change in terrestrial systems extend not only from shifts in populations of plants and animals but to reductions in net primary production and to increased fluxes of nutrients into waterways. Thus we can predict with broad accuracy the effects of long-term exposure of forests to acid rains. We will be able to predict in detail the amount of acidity required to cause varying degrees of damage. We require now, first, recognition of the patterns of change associated with chronic disturbance; second, the establishment of quantitative relationships between disturbance and the degree of change produced. The work must be both terrestrial and marine. It spans the full gamut of studies of natural ecosystems. The knowledge gained from it, however, will be the basic knowledge required for management of the earth's surface.

The third topic is somewhat less ephemeral and one in which I have acquired considerable recent experience: the treatment of sewage. The review that I have offered here makes it abundantly clear that the pattern of sewage disposal we have developed over the past century or so is totally inconsistent with continuously expanding and ever more intensive use of environmental resources. Even the most modern and bold steps in the current pattern will not stand scrutiny under this test. The development of large collecting systems for urban areas with the objective of releasing treated sewage into the coastal oceans makes no sense whatsoever if one recognizes a shortage of fresh water, a shortage of fertilizer elements, the problems of pollution of coastal oceans, and an increasing shortage of energy. One of the costs of having cities is the recovery of sewage, the release of usable fresh water into places where it will be available again, and the recovery of nutrients.

The possibilities for making changes in the patterns of treating sewage are being explored in various places around the world. They include especially the use of man-made or natural ecosystems for filtering particulate matter, absorbing nutrients, and releasing fresh water either into surface water courses or into ground water channels. Experience at Brookhaven over the past several years has led me to be convinced that both of these are practical approaches. It is possible to devise agricultural and natural terrestrial communities, used in sequence, to treat sewage over the long term. The treated water is released into the ground water for reuse as drinking water. It is also possible to treat sewage on the surface by a combination of marshes and ponds and to release the treated water into a variety of uses including the irrigation of agriculture or the recharge of streams. These studies obviously have a much longer term to run but their potential cannot be dismissed.

Some such plan for management of liquid wastes is clearly essential. When coupled with the requirement that industrial wastes not be introduced into municipal collection systems but be treated at the site of the industry, the development of biotic communities for the management of both water and nutrients in domestic sewage becomes very attractive indeed. It offers the possibility of larger numbers of smaller treatment facilities located in various places rather than simply on the margins of rivers or bays in places where disposal of water in large quantities is convenient. It is my belief that the EPA must pursue these techniques with all vigor immediately and that the proceeds of this research will be extraordinarily rewarding.

The issues of management of environment seem excessively complicated, coupled as they are to economic interests, to historical views of rights in resources, to traditional views of politics, and to what every man thinks of as his own personal freedom. They are complicated only if we wish them to be so. The central principles of the science of environment are no more complicated than the central principles of thermodynamics or literacy or arithmetic. Their essentials help us see with some clarity and simplicity what is happening and how to solve the problem.

The problems can be solved but only by rearranging our approaches into a pattern that can lead to a solution. To the extent that we devote ourselves to accentuating the trends of the past decades that tend to cause the further diffusion of human influences around the globe, we become causes rather than cures. There is a powerful argument at present that much of the scientific effort of the country including that of some of its major national laboratories is more detrimental than constructive. It is long past time that we changed this situation.

REVIEW OF THE PAPER BY G. M. WOODWELL

Sidney R. Galler
U.S. Department of Commerce

Dr. George Woodwell is a distinguished ecologist whose contributions to our understanding of natural ecosystems have deservedly received high praise and international recognition. It is not surprising, therefore, that the high point of Woodwell's presentation is his eloquently articulated ecological perceptions which, appropriately enough, come into sharp focus midway in his paper: "In a world condemned to soaring populations and more rapidly soaring demands on resources, not to speak of demands on the regulators, the basic pattern in use of the environment must be the closed system: countries that do not infringe on one another by fouling air or water held in common; . . . . The basic principle is no pollution; not pollution within limits."

However, the intellectual climb up to this sunny promontory is both steep and labored for this reader. The descent is even more precipitous with the high point of the discussion quickly lost in a mist of pessimistic observation on the state of mankind's environmental affairs, simplistic diagnosis of the environmental maladies, and an ingenuous prescription for solutions.

I find no fault with Woodwell's basic proposition even though I am not prepared to rule out the potential for developing a technology that could yield enough energy to meet human demands without degrading the environment. However, I do take exception to his opening Georges Bank illustration and I disagree vigorously with his proposed designation of a Federal regulatory agency to be responsible for the support of the

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requisite research programs that will have to provide the knowledge for meeting the needs of both man and his natural environment.

First, let us examine the validity of Woodwell's selection of the proposed outer continental shelf oil development in the Georges Banks area as the opening scene in his scenario for justifying his concept of the closed system. The Georges Bank controversy, while genuine, derives from the spurious notion that offshore oil development and a healthy commercial fishery must always remain mutually exclusive. It has yet to be established that outer continental shelf-oil exploration and extraction are intrinsically harmful to marine fisheries, notwithstanding vociferously voiced allegations. The facts are that the great bulk of oil pollution of the oceans stems from a combination of tanker deballasting operations and runoff from shoreside point sources. Oil pollution resulting from accidental oil spillage, e.g., tanker collisions, pipeline ruptures, etc., runs a distant second, while oil pollution from stationary platforms, including the Santa Barbara channel episode, has been negligible by comparison.

Undoubtedly, sloppy practices and inadequate quality control measures have caused oil pollution and damage to marine ecosystems in certain locations. However, I take issue with the Spenglerian-like view that offshore fixed platform oil developments must invariably be inimical to the maintenance of marine fisheries or marine ecosystems in general. It has been demonstrated on many stationary drilling and pumping platforms that scrupulously observed safety practices utilizing currently available technology can protect the marine sports and commercial fisheries in those areas.

The offshore oil development versus commercial fishery argument typifies a rather tendentious and sometimes sanctimonious environmentalist handwringing. This attitude handicaps objective and constructive cooperation among the principal sectors of our society towards protecting the natural environment without eroding the quality of life of man.

In my view, the competitive pressures on the world's arable lands causing their removal from agricultural production would have been much more supportive of Woodwell's thesis. While a relatively small percentage of the world's population is dependent upon marine fisheries for its principal source of protein, the vast majority of the peoples of the world are completely dependent upon the products of agriculture (much of it imported) for their survival. The Arab oil embargo, followed by the OPEC quadrupling of oil prices, have had devastating effects on both agricultural and fishery economies of many of the nations of the world. It is not easy for a developing nation to sustain a rapidly growing population with a "two-mule" agriculture or a "sailboat" fishery. A rich commercial fishery which cannot be fished because the fishermen are unable to pay the high price for oil is of no benefit from a practical point of view to a protein deficient population. Thus, while one may agree with Woodwell's ultimate goal, support for his thesis is eroded by the doubtful validity of his supporting illustration.

Dr. Woodwell's proposal, presaged by the title of his paper "Research for Regulators," reminds one of the comment attributed to the distinguished scholar, Sir Ritchie Calder, to the effect that science yields knowledge, not wisdom. Wisdom derives from knowledge tempered with judgment. One might add that since sound judgment frequently derives from experience, one might assume that Dr. Woodwell's experience with regulatory agencies has been rather limited. His notion that the Environmental Protection Agency would be the appropriate agency for sponsoring basic research needed to preserve ". . . . the earth's basic chemical and biotic patterns," is naive in my opinion. One does not subtract from the Environmental Protection Agency's well deserved credit for sponsoring this symposium, by taking exception to Dr. Woodwell's proposal to assign to it a national research responsibility, the implementation of which could exceed the capabilities and resources of all of the civilian Federal R&D agencies lumped together.

If the achievement of Dr. Woodwell's ultimate goal is as important for the future of mankind as I believe it to be, then the knowledge required to achieve that goal must perforce derive from a wide variety of basic and applied research investigations, many of them seemingly unrelated. The identification of research objectives, as well as the selection of the requisite cadre of competent scientists and technologists from the natural and social science disciplines will require a capability for research program planning and administration that may well extend beyond the available resources in the oldline and experienced, R&D agencies like NSF, NIH, and ONR; much less a small, albeit capable R&D unit within a single, mission oriented regulatory agency like EPA.

Perhaps the most prescient of Dr. Woodwell's views is his assertion that "The basic resource in support of human activities is carbon fixed in photosynthesis and made available in various forms to man. There is abundant evidence that the world carbon budget is being affected grossly by human activities." The validation of that assertion and the means to minimize and perhaps eliminate man's adverse impacts on the global carbon budget merits the highest priority attention from legislative and executive branch leaders, and certainly deserves both the development of a unified national policy and the coordinated mobilization of our national intellectual and material resources. Anything less than a carefully orchestrated national program of research and development cannot do justice to our ultimate goal (so perceptively presented by Dr. Woodwell) of protecting the life support capacities of our global environment while at the same time delivering the necessities and amenities which in the aggregate add the dimension of quality to the human experience. Certainly Dr. Woodwell's thesis deserves more than any single regulatory agency could possibly deliver.

RESEARCH NEEDS

FIFTH VIEWPOINT

SCARCITY, GEOPOLITICS, AND RESOURCE MANAGEMENT

John Zierold

Overview

The United States and the entire world are in the midst of sudden transformations that have led to the most massive shift of capital wealth in the history of mankind. It is a situation which has led to a multiplicity of crises with which the industrialized nations as well as the underdeveloped countries cannot cope.

The result of the energy crisis, brought about by the oil embargo, has been the imminent prospect of starvation for millions in India, Sahel, West Africa, and Latin America. The energy crisis and the world food crisis bring the greatest challenge to this country it has yet faced, and will bring about discontinuity in resource management whether we like it or not. Actions taken by the other nations will affect us to an extent greater than we have anticipated and choices will be forced upon us despite our unwillingness to acknowledge their existence.

Possible Impacts

The world food crisis is really the sum of many crises: the energy crisis, the population crisis, the urbanization crisis, and, most critical of all, the policy crisis.

The population growth rate worldwide is 2 percent per annum, which means a doubling time of approximately 35 years. Thus, shortly after the year 2000 there will be 6 billion inhabitants to be fed, employed, and governed. That figure is not the top of speculative conjecture, but, in fact an ineluctable mathematical certainty.

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There is serious doubt that all these billions can be properly nourished, let alone saved from famine. With the fourfold increase in the price of petroleum--soon to be bumped upwards again--it is clear that countries like India and Bangladesh have been priced out of the fertilizer market, which seriously hampers their food production. The same is true for many other countries too numerous to list.

How to deal with this awesome spectre is beyond the comprehension of virtually everyone. Yet it is a crisis that will not go away and one for which this country and all other countries must prepare with the least possible delay.

Some, like Professor Garrett Hardin, may argue for the adoption of lifeboat ethics, by which they mean that we must resist our humanitarian impulses and allow the starving to perish--in order that they do not reproduce and therefore create famine and death of even greater magnitude in the decades to come. It is a seductive theory for the affluent nations, which can cool down the fever of their conscience through the ministrations of situational ethics. But the hard, bitter reality is that we cannot sail Professor Hardin's lifeboat unmolested through a sea teeming with people who wish to climb aboard. In point of fact, Hardin's metaphor is ill chosen. The better comparison is a long train with one firstclass carriage--in which the rich nations dine on the most lavish provender--and a hundred cattle cars crowded with the hungry who at any moment may move up to the firstclass carriage and take it over.

Possible Policy Responses

Assuming that the United States were to adopt the lifeboat ethic as the linchpin of its foreign policy, and assuming further that other rich nations did the same, then we would see before long the rise of iron governments in the third world: elite coalitions of military and civilian interests based, probably, on either the Red Chinese or

Brazilian model. Wars of redistribution or forced migration, nuclear blackmail for a share of the world's food and other resources would be all too likely an outcome.

This scenario must surely be evident to those who compose white papers deep in the recesses of the Pentagon and the State Department: those experts who now are fumbling with such mercurial policy questions as how to ameliorate energy shortages through energy independence in this country, and how to frustrate Persian Gulf hopes to extort foreign policy decisions from our allies in Western Europe and elsewhere.

One possibility under consideration must certainly be the large scale extraction and use of shale oil and coal. With some 300 years of coal reserves, the production of petroleum substitutes for use here and for the supply of our allies to insulate them from the harsh winds of embargo, must certainly be seen as a tempting solution to impending disaster.

The nation that can export energy and food will exert its logic on other governments in a way enormously more effective than the use of armaments in the post World War II period.

Environmental Consequences

The impact of strip mining the Great Plains for coal, pulverizing the Rockies for shale oil, and scaling ever upwards highly mechanized fertilizer and energy intensive agriculture, suggests the possibility of very grave consequences indeed. To pursue such a course of action carries with it the possibility that we will confront biological and physical laws under the harshest and most punitive of terms for the loser.

All this suggests that we must begin now to formulate research priorities that reduce the enormity of these impending problems. Research policies properly drawn will not stultify economic growth, but enhance it. The late 1970s and the decade of the 80s will see the emergence of a vast and profitable new industry: how to make sense out of change.

Suggested Research Programs

Our view of the future is too often based upon a body of conventional wisdom, but that orthodoxy is useful only under trouble-free scenarios; i.e., so long as there are no factors inducing major system breaks--discontinuities caused by such phenomena as resource limitations, market saturation, or a slow response to crisis by a rigid bureaucracy. In essence, anything that has not happened in the past is not accounted for in the conceptual models based upon the conventional wisdom. As a result, as a harbinger of the future, conventional wisdom has been shown to be no more accurate in anticipating the current economic difficulties than it was in predicting or projecting the impacts of the energy crisis.

It is clear, therefore, that to more accurately predict the future we must understand the interrelationships and trends that now shape it.

Cheap energy has fostered a throw-away society. As the cost of energy increases, the social and economic impacts may cause significant changes in historic trends. Labor-intensive, as opposed to energy-intensive industries will be encouraged and a society will evolve that stresses reusability as opposed to discard. These changes in trends can be called system breaks, and they are the surprises in the future unanticipated by practitioners of conventional wisdom.

Environmental Impacts and Economies of Urban Densities

The nation can no longer afford sprawl. In a recent study, the Council on Environmental Quality compared the costs of low-density sprawl with those of high density. It found that sprawling communities use up to 44 percent more energy and 35 percent more water, while high-density communities produce 45 percent less air pollution.

Largely as a result of private auto-intensive transportation systems, U.S. urban centers have expanded as sprawling low-density suburban areas. It has recently been widely recognized that this low-density sprawl has caused air pollution, consumed vast quantities of prime agricultural land, and helped bring about the energy crunch. As a result, recent efforts in some sectors have been aimed at reducing sprawl and promoting greater densities.

Containment of the city is an economic imperative. Consider the distribution of water. Mr. Gordon spoke about extrapolating the forces at work for greater and greater consumption; and that the doubling of the world's population--if people were to exist at our levels of consumption--would mean before long that the planet would be virtually picked clean of its resources.

If one doubles peoples' water supply by doubling the service area, at constant density, it is necessary to accept the cost of doubling pipe mileage, the cross-section of the old system, and upgrading pipe joints to hold extra pressure. And that is but one feature of the economies of density.

In some circumstances, however, greater numbers can be accommodated without doubling. If the demand for water doubles within a fixed service area, it is not necessary to double all the service facilities. It is probable that it would only be necessary to expand all pipe diameters--not by double, but by the square root of two, since--as mathematicians tell us--cross-sections increase with the square of the radius.

On the other hand, the environmental effects of increased urban densities are not obvious. It is clear that with less sprawl, per capita miles driven should be reduced, resulting in less per capita air pollutant generation. However, with the increased density, the concentration of air pollutants may, in fact, increase. Although less energy would be used for transportation, denser urban areas may be more energy intensive to provide for cooling (due to urban heat island effects) and for high-rise living if that is the trend. It may be necessary to provide for more vegetation and green areas as sinks for air pollutants and as climate moderators.

Environmental Impacts of Recovering Subeconomic Deposits

Many estimates have been developed of world reserves of various materials, known deposits recoverable with current technology and at current costs. Other estimates consider so-called hypothetical and speculative deposits--supplies occurring in lesser concentrations, in more remote locations/depths and of lesser known quantities. These deposits are cited as evidence of no serious material shortage problems. However, it should be recognized that all other than proved resources require significant increases in expenditures (including operating costs, capital investment, energy costs, and technology improvement) to make recovery of these resources feasible. In addition, it is also essential to consider the potentially huge environmental impact of recovering materials in small concentrations from isolated or environmentally sensitive locations. Taken together, such considerations may put many supposed material deposits out of reach.

Research programs should be formulated to identify existing quantities of subeconomic deposits of critical materials. The locations and physical conditions of these deposits should be determined. Finally, the environmental impacts of recovering these deposits should be evaluated.

Environmental Costs of Mineral Extraction and Processing

In the extraction, transportation, processing, use, and disposition of goods and materials, the protection of the environment--especially air and water--has historically been largely ignored. Our market system that allocates the use of material resources by putting prices on them has traditionally regarded environmental resources as free goods; they have customarily not been written into the equation for the cost of producing goods and services, and have therefore not been reflected in the prices consumers have paid. Unless the true costs of commodities are reflected in their prices, there is a tendency to over-consume certain materials or to delay development of substitutes when such development is in the public interest. A related example is the fact that cost/benefit analyses of highway systems rarely if ever include the costs of air pollution attributable to cars. These costs are borne separately by other agencies (e.g., EPA) or by consumers through increased health care costs.

These considerations are of special relevance in the case of minerals. Improper pricing policies can result in the unnecessary depletion of strategic minerals.

Preservation of Prime Agricultural Lands

Worldwide increases in food production have been obtained by the use of high yield "green revolution" crop strains and the increased use of fertilizers and pesticides. Green revolution crops are extremely fertilizer sensitive--great quantities of fertilizer are required and the use of lesser quantities results in smaller yields than would have been achieved by older, unimproved strains. In addition, the newer improved strains are more susceptible to a greater variety of pests.

With the fourfold price increase in crude oil, the supply of petroleum-based fertilizers and pesticides has been put out of reach of less-developed countries. For every million tons of reduction in fertilizer supply, there is a corresponding 10-million-ton drop in grain production in these countries. Moreover, the problems will become worse, since a worldwide shortage of nitrogen-based fertilizers is likely to occur over the next several decades because of the anticipated shortfall of natural gas.

Such developments will exert pressure on the use of more lands for the production of lower yield and less energy-intensive crop strains. However, significant quantities of prime agricultural lands are lost to urbanization each year in the United States. Preservation of these lands will be essential as will be development of less petroleum-intensive means to make these and other lands more productive.

Preservation of Green Spaces Within Urban Areas

With pressures for increased density within urban areas, the amount of open space land preserved within urban regions may rapidly decrease. There is growing evidence, however, that those lands serve important purposes in urban regions. They permit natural recharge of ground water supplies (much development has occurred in prime recharge areas thus exacerbating ground water depletion problems); vegetation helps to save energy by cooling areas (by transpiration), while reducing dust and noise pollution levels; vegetation has been shown to be an important element in reducing concentrations of air pollutants since many plants naturally uptake many air pollutants, e.g., sulfur dioxide, nitrogen dioxide, and ozone. Furthermore, many urban areas include marsh lands, which have been found to be of great value for tertiary wastewater treatment. It is important that these benefits be recognized by planners and policymakers so that provisions for the proper preservation of such lands be undertaken before open space lands within urban areas are completely lost to development.

REVIEW OF PAPER BY J. ZIEROLD

Frank P. Sebastian
Envirotech Corporation

I should like to go through John's excellent paper commenting in the areas where I feel I may have something to offer: for instance, his reference to nuclear blackmail for a share of the world's food and other resources from such governments as his example of the People's Republic of China (PRC). I would add that, having had an opportunity to visit the PRC in 1972 among the first 30 Americans who visited mainland China after that 20-year gap, I learned two things that relate to the scenario John drew out. The Chinese say, contrary to what we and they learned in school books, that they are self-sufficient in oil and are able to provide all their oil resources.[1] In fact, they are exporting oil to Japan and possibly to other countries.

Along with this, representatives of the PRC also reported that after years, decades, generations of starvation they were now substantially able to feed themselves. My wife and I visited two of their communes--one, particularly, outside Canton that was the county seat for 980,000 people. It was pointed out by commune leaders that following the PRC's takeover of the government 20 years ago a decision was made to augment the reuse of nightsoil, or the recycle of waste material, which they had been practicing for centuries, by using chemical fertilizer. Later I learned from U.S. Commerce Department reports that the exportation of Japanese chemical fertilizer to the Chinese was really the basis for the rapid growth of the Japanese fertilizer industry following World War II. The Chinese imported vast quantities of chemical fertilizer, increased their food production, and then embarked on a program of building fertilizer plants in the communes. In the communes we visited, there were fertilizer plants of various sizes that were much smaller than anything we would consider building in the United States today.

The point I want to make is that it was only through the addition of chemical fertilizer that the Chinese were able to increase their food production and, since 1970, to be self-sufficient. In one brigade at Tung Fan County they pointed to a granary of rice and said, "We are no longer at the peril of the drought or flood; we have several years' supply of grain and are able to sell some of our production."

So hopefully in other lesser developed countries there is some parallel opportunity for improvement in food production that will help reduce the number of people trying to get on John's proverbial lifeboat.

In connection with environmental consequences, John states that research policies, properly drawn, will not stultify economic growth but enhance it, and with that I most heartily agree. I think Mr. Ruckelshaus in his excellent paper set the stage for this when he talked about having four times as many economists in his agency as he had ecologists. It is in this arena that the studies on the benefits of pollution cleanup and the elimination of damages from pollution are really critical economic and social factors. I am referring to damages created from pollution that are being suffered by us individually, and are being paid for by us individually. We sorely need more research on these social costs, as well as on the extent to which air and water pollution cleanup will eliminate damages so that the figures will be less controversial and we can have broader support of them.

These facts are just emerging in the United States and are not generally recognized. However, England was the first country to take stringent action on a national pollution problem and reap the national benefits.

Let me shift the subject to air pollution and draw on the message from President Nixon to the Congress to illustrate:

> "In London in December 1952 an air pollution episode lasted five days and was associated with 4,000 excess deaths. During the episode 1,100 patients per day, or 48 percent above normal, were admitted to the hospitals of London."

I would like to add that four years later stringent air pollution control legislation was passed in England, but it was not until 14 years later that tangible benefits were broadly reported. Sunshine increased over 50 percent in London in December, infamous London fogs disappeared, and rare birds--the snow bunting, the hoopoe, and the great northern diver--have reappeared. House martins have returned to nest near Primrose Hill after an 80-year absence. Though no estimate is available, substantial savings can be expected in reduction of the $700 million of annual damages from air pollution. The national cost of controls was $1 billion over 10 years.[2]

Table 1 shows 1972 EPA figures for water pollution; it indicates that cleanup yields some overall savings. The benefits of water pollution cleanup can be observed this way: that the damages throughout the United States were estimated at about $12.8 billion. The savings from cleaning up that water were estimated at about $11.5 billion, whereas the costs in that level of cleanup were only about $6.3 billion, giving a net savings of $5.2 billion.[3]

In the air sector, we have a somewhat similar equation. The damages were estimated at $16.1 billion, the savings through cleanup were $10.7 billion. The cleanup costs at that time were estimated to be less than $4 billion, giving a net savings of about $6.8 billion. I believe those figures include something like $6 billion a year for health costs.[3] Subsequent reports estimate that the cost of treating environmentally caused illnesses amounts to something over $30 billion a year.[4] There is, thus, a huge potential increase in the savings figure if those medical figures are correct. Of course, here is an area that I am suggesting needs a great deal of research attention to improve the accuracy of the savings figures so that they can be used with a greater degree of confidence.

Table 1

BENEFITS OF WATER POLLUTION CLEANUP

	Annual Amounts	
	All USA	Per Family
1972 damages	$12.8 billion	$213
Cleanup savings	$11.5 billion	$192
Cleanup costs	$ 6.3 billion	$105
Net savings	$ 5.2 billion	$ 87

BENEFITS OF AIR POLLUTION CLEANUP

	Annual Amounts	
	All USA	Per Family
1972 damages	$16.1 billion	$268
Cleanup savings	$10.7 billion	$178
Cleanup costs	$ 3.9 billion	$ 65
Net savings	$ 6.8 billion	$113

As a result of the end of cheap energy, John pointed out, there will be an era where labor-intensive as opposed to energy-intensive industries will be encouraged. Certainly, a reevaluation must take place. However, our societies individually will reorder their priorities and may not go all the way. For example, this past Sunday when I was in Athens, the traffic jam at 10:00 o'clock in the morning was enormous.

The cab driver explained that it was hot and the Athenians were going to the beach. In talking about other things we learned later that the price of gasoline was $3.00 a gallon. By our normal logic, we would think that when the price reached $3.00 a gallon for gas we would find some other way to get to the beach besides using our individual automobiles. But that does not seem to be the case in Greece, which is already facing these kinds of problems.

Rather than totally labor-intensive industry being developed, I would think that improved efficiency through improved technology offers an intermediate ground and will present great opportunity for R&D activities.

With regard to the problems and opportunities in R&D for increased water demand, as pointed out by John Zierold, I think here a partial technical answer lies in the field of water reuse. The incremental cost of producing reusable water is less in many cases than the costs of water from new sources. The incremental cost will narrow further as the 1983 effluent standards are met. Another benefit to figure into the equation is the elimination of the cost of damage from polluted water, as well as a huge plus from the value of the reclaimed water!

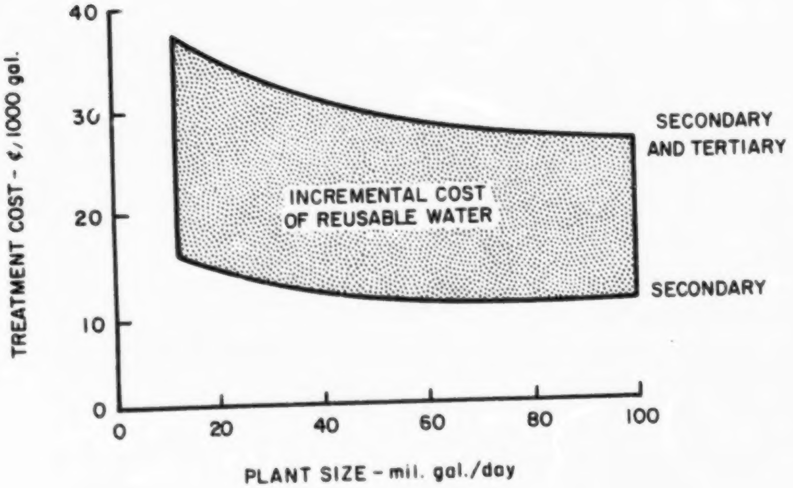
To further illustrate, there are economic advantages to upgrading existing plants to produce high quality effluent suitable for reuse. The incremental cost to achieve high quality water over and above secondary effluent is shown in Figure 1. Secondary treatment is assumed as the base standard. The tertiary treatment incremental costs are for upgrading secondary treatment processes to facilities that would produce an effluent complying with WHO or in laboratory tests with USPHS standards. (The USPHS standards do not apply to reclaimed water even though the water meets the required laboratory tests.) The assumed tertiary treatment consists of lime clarification, filtration, and carbon adsorption, as well as reclamation and reuse of the lime and carbon, and thus has favorable environmental impact.

Given the incremental cost to produce a reusable quality water in most existing plants, the potential net benefit of this water can be estimated. This benefit is the difference between the present market value of tap water and the incremental cost of producing the tap water from secondary effluent (Figure 1).

The present market values for tap water vary widely across the United States. For example, in the San Francisco Bay Area, tap water costs range from about $0.18 to $0.38/1,000 gal ($0.048 to $0.10/m^3), and price increases have been reported since 1972 and to 1975. Figure 2 shows the estimated net potential benefit of water reclamation that can be realized by adding tertiary treatment to a conventional plant.

Any projected cost for increased supply of tap water (for a given flow) that lies above the marginal cost curve will realize a benefit for reuse. For example, if an average cost of tap water is assumed to be $0.25/1,000 gal ($0.066/m^3), the benefit of reclaiming wastewater with tertiary treatment would range from $0.03/1,000 gal ($0.008/m^3) at 10 mgd (37,900 m^3/day) to $0.12/1,000 gal ($0.032/m^3) at 100 mgd (379,000 m^3/day). These benefit statistics indicate that water reuse offers a unique opportunity not only to eliminate pollution but also to reuse a finite, limited resource economically.

Not only will water reuse make good economic sense in many cases, but dwindling freshwater supplies for agricultural, industrial, and municipal needs will make it a necessity in the future. In 1957 the total freshwater use in the United States began to exceed the dependable supply. The gross water deficit is expected to increase for the foreseeable future, far outstretching the total supply capable of development by the year 2000. The only way to overcome the deficit is through a greater reliance on water reuse.



Note: January 1971 cost (6%, 25 yr.) amortization included

FIGURE 1. COST OF CONVENTIONAL AND ADVANCED TREATMENT OF WASTEWATER

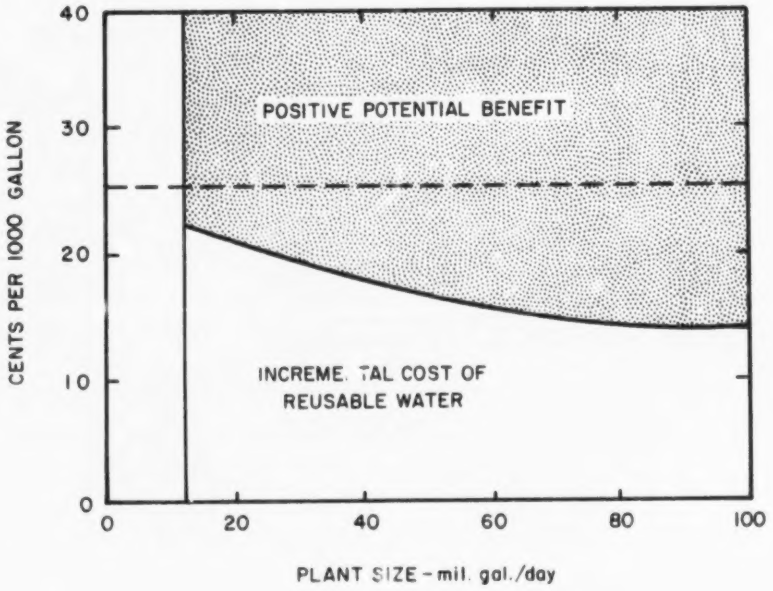


FIGURE 2. POTENTIAL BENEFIT OF WATER REUSE

What is the problem with this scenario? We have not done the necessary health effects R&D to be sure that the reclaimed water can be cut into the tap supply. Also, the evaluation of any psychological considerations should be undertaken to obtain all the necessary answers to permit the safe and widespread use of reclaimed water.

A great deal of effort needs to be put forward in sounding out the true public attitudes toward the direct reuse of water. I think the perceived public attitude is that the public is unwilling to come to grips with reclaimed water. However, a U.S. government survey of 155 cities with populations over 25,000 using surface water showed that 145 of them have some raw waste in the water supply and up to 17 to 18.5 percent raw waste in their source of water in the dry season. Cleveland, Ohio gets its drinking water from Lake Erie, which is known to contain industrial and municipal wastes. London obtains about one-fifth of its metropolitan drinking water supply from the River Lee, 10 miles (16.1 km) downstream from the Rye Meads Treatment Plant, the highest quality wastewater treatment plant in the United Kingdom. Paris draws its tap water from the River Seine, but I am told that France is a bottled water society.

A recent U.S. Public Health Service (USPHS)[6] survey of community water supply systems showed that 41 percent of the systems, serving one-third of the study population, delivered water with a quality lower than the effluent from some of the advanced waste treatment plants to be discussed. Projected nationally, this is equal to about 50 million people in the United States drinking water of a quality lower than that produced from an advanced waste treatment plant.

Most recently, of course, the great conduit between dirty water and clean water has come to light in terms of the New Orleans tap water report, and I suggest that it would be a great contribution to determine what indeed the public attitudes are toward direct reuse of water and make the additional R&D necessary to determine the long-range health effects from such use.

I should mention that there is one plant that some of you know has existed since 1967,[7] and that is directly recycling sewage into its tap water supply. There was no public outcry when the plant was turned on. I visited the plant--in Windhoek, Namibia--in 1969; I'll always remember the moment of truth when my daughter poked her head out of the bathroom with a toothbrush in her hand, saying, "Is it safe to use the water?" I knew that 30 percent of the water supply came directly from the sewage treatment plant. But they had done all of the reliability, viral, and epidemicological studies that showed, as we also found, it is safe.

However, this brings up a curious facet about technology. The technology used in Windhoek to treat the water is not greatly dissimilar from that used at the Lake Tahoe, California Water Reclamation Plant, but their technicians were not sure that the technology existed to economically regenerate the activated carbon used in one of the process steps. So they just spread the spent, expensive material on the ground. From experience in the United States we knew that one could economically regenerate carbon and reuse it on site. Conversely, we are not sure one can safely drink the water. So we throw away the water!

I should like to cite some specific examples of the state of the technology; i.e., the technology on which the equipment manufacturers are bidding, and indeed guaranteeing performance today without waiting for any additional R&D output.

I suggest that in developing future R&D programs, serious consideration should be given to such existing technology as that in operation at the South Tahoe Water Reclamation Plant which is one of the most advanced plants in the United States. This 7.5-mgd plant, as you undoubtedly know, has been operating since 1967 and has been converting municipal sewage to a water that will meet laboratory tests for drinking water; it has not failed to meet its standard for the full period of its operation. Please note that I am not saying that this water can be connected directly to the U.S. tap water supply, but it will meet laboratory tests for drinking water, and, as we all are now aware from recent reports on contaminants, much of the surface water in our tap supplies today does contain elements of sewage effluent that have not been anywhere near as highly treated as the Tahoe wastewater.

A key aspect of this most advanced plant is the sludge processing and handling, for as you increase the level of pollutants removed you increase the amount of sludge generated. The Tahoe plant received a generous amount of federal funding for the liquid stage but it was not until the Clean Water Restoration Act of 1966 was passed in December of that year, providing R&D funds, that sufficient money was available to install the solids handling and processing system. Tahoe received one of the very first R&D grants under the 1966 Act for over $1 million to demonstrate an incineration/reclamation process that would reclaim the treatment chemicals--lime, in this case--for on-site reuse.

It is pertinent to my point that although this sludge project was fully funded by the federal government as an R&D project the successful equipment bidder had to guarantee the performance of this equipment, thus in effect guaranteeing the results of an R&D program. The results specified were achieved. Thus, for the first time it was demonstrated that a complete environmentally compatible wastewater treatment plant could make a drinkable quality water from sewage, reclaiming chemicals on site, and converting all residue to a sterile ash that, as I shall mention later, has some other resource reclamation potentials.

You may be wondering: "What about the impact of the incineration reclamation process on the pristine air quality in the Lake Tahoe area?"

The environmental impact on the air quality is nil: there is no visible plume and the highly cleansed exhaust gases are recirculated through partially treated waters at one stage of the process to reclaim the carbon dioxide for reuse in the process.

Both of these facilities involve conventional biological treatment with a tertiary physical chemical treatment facility added. Since these plants were built there have also been other industry and government developments in physical chemical treatment, commonly called PCT processes, which are of great significance. In July 1971 the EPA announced its lime/activated carbon physical chemical process, including on-site lime and carbon reclamation through high temperature thermal processes.

My company has also developed somewhat similar PCT processes that produce a product water comparable to Tahoe quality water. A further step of development in sludge processing beyond that achieved at Tahoe has been attained which combines in a patented process the two steps of lime recovery and incineration into one step utilizing the fuel value of the sludge as a partial source of fuel to reclaim the lime for on-site reuse. Several plants utilizing these PCT processes are currently under construction involving many millions of dollars of EPA construction grant support.

nother industry development, similar to one in the current EPA R&D budget, is that of energy reclamation from sewage plants. Although I have already mentioned reclamation of the fuel value of sewage sludge to reclaim chemicals on-site for reuse, this has been taken a step further in three EPA-funded municipal plants currently under construction involving the use of third-generation multiple-hearth furnace systems called Closed Loop Energy Systems (Figure 3). In these systems a sludge heat treatment step is installed to break loose the water bound in the biological cells to enable normal dewatering equipment (vacuum filters or

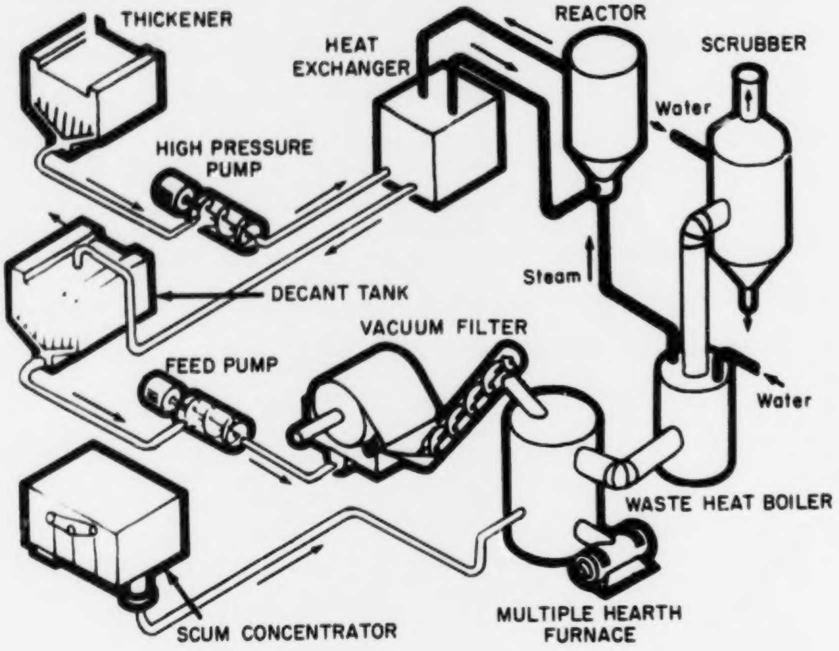


FIGURE 3. CLOSED ENERGY LOOP, SLUDGE HANDLING SYSTEMS INCORPORATES HEAT TREATMENT, INCINERATION, AND HEAT RECOVERY

centrifuges) to be used to obtain a 250 percent increase in the normal solids content of the sludge. This brings the sludge to a fuel value approximately equal to that of soft coal. The heat-treated sludge is then processed through a similar but differently designed furnace to convert itself to a sterile, potentially useful ash without the need for auxiliary operating fuels and with sufficient excess heat reclaimed to provide process heat and steam at the treatment plant.

Because of the often prevalent view of the strong need for more sludge processing technology, you must be wondering about the impact upon air quality of these incineration/reclamation units. Thanks to both EPA and industry-sponsored R&D activities in detailed analyses of the exhaust gases, the heretofore unknown environmental benefits of these processes have recently been discovered. Several points are worth noting:[8]

(1) These combustion units will meet the new air quality standards under the Clean Air Act.

(2) The exhaust gases have been ruled by one of the most stringent air pollution control agencies in the United States, the San Francisco Bay Area Air Pollution Control District, to have an insignificant impact on air quality.

(3) Combustion decomposes worrisome pesticides, such as DDT and 2,4,5-T, that may be contained in the sludge at normal operating temperatures at no extra cost, and such materials are not contained in the exhaust air or in the ash product.

(4) Destroyed in the process are polychlorinated biphenyls (or PCBs), which have been determined by the EPA to be the most persisent of the chlorinated hydrocarbon group found in sludge. In fact, based on a search of the literature, it would appear the only way that PCBs are being removed from our environment once they are introduced is through modern sludge incineration as employed at wastewater treatment plants.

Although EPA research efforts of 1971 and 1972 were uncertain as to the fate of incinerated PCBs, independent laboratory tests sponsored by private industry showed that PCBs and most of the other substances on EPA's proposed toxic chemicals list were destroyed under normal operating temperatures. EPA-sponsored tests in 1974 confirmed these 1972 data, showing the complete decomposition of DDT and 2,4,5-T.

(5) These systems control heavy metals contained in sludge. Mercury in the EPA proposed toxic substances list was found, contrary to conventional thinking, to be controlled. From 83 percent to 96 percent of the trace amounts of mercury normally found in sludge is removed from the exhaust gases in two different multiple-hearth installations. These studies were sponsored by the EPA air quality group at Research Triangle Park.

(6) These systems employ recovery processes to reclaim both lime and carbon dioxide in advanced PCT plants.

(7) They create a product--ash--that is potentially useful as a quasi-fertilizer because it normally contains 6 percent to 15 percent phosphate (Table 2). Over 50,000 tons of sludge ash have been used experimentally in Japan as a quasi-fertilizer and deserve more R&D consideration. Sludge ash is purified of PCBs and pesticides and, because the nutrients are more concentrated, has a potential value of $48.00 per ton--four times that of wet sludge (Figure 4).

To bring the air quality impact of advanced sludge combustion systems into perspective and to furnish the basis for future R&D needs, it would be helpful to compare automobile pollution emissions with exhaust emissions from sludge combustion equipment. When comparing one average automobile, which reportedly travels 12 miles per day, against the air quality impact from sludge combustion on a per capita basis, we find that sludge combustion is about equivalent to burning one ounce of gasoline in an automobile. With sludge combustion, however, we are removing harmful chemicals from the environment and reclaiming increasingly precious resources--water, lime, carbon, and others. A detailed comparison of these emissions is shown in Figure 5.

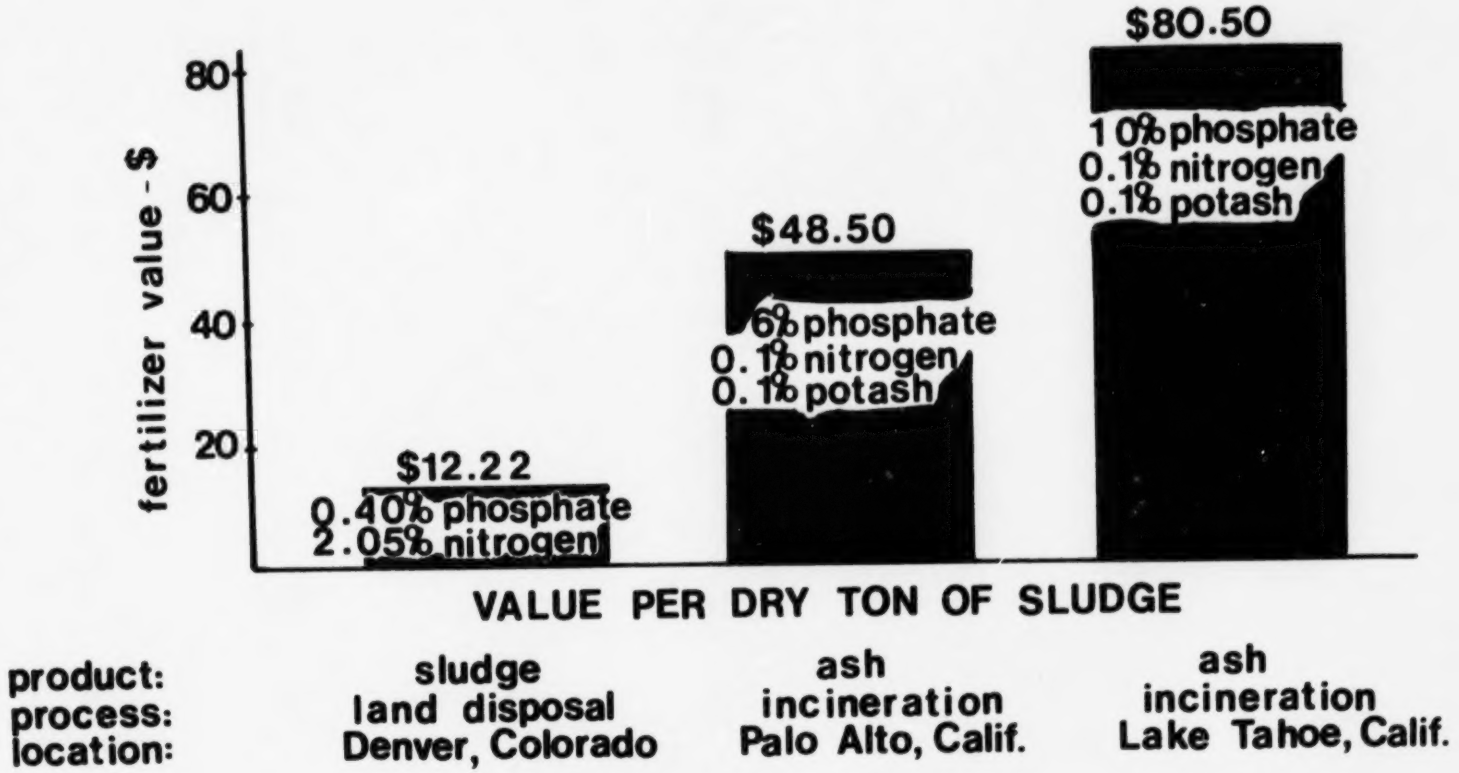
What about the costs of this treatment technology? In the GAO report to the Congress on EPA R&D last year, it was stated that "The high cost of sludge handling and disposal is well recognized." Well, let's take a look at those costs.

Table 2

TYPICAL ANALYSIS OF ASH FROM TERTIARY QUALITY ADVANCED WASTE TREATMENT SYSTEM

	Percent of Total	
	Sample 1 Lake Tahoe 11/19/69	Sample 2 Lake Tahoe 11/25/69
Silica (SiO_2)	23.85	23.75
Alumina (Al_2O_3)	16.34	22.10
Iron oxide (Fe_2O_3)	3.44	2.65
Magnesium oxide (MgO)	2.12	2.17
Total calcium oxide (CaO)	29.76	24.47
Available (free) calcium oxide (CaO)	1.16	1.37
Sodium (Na)	0.73	0.35
Potassium (K)	0.14	0.11
Boron (B)	0.02	0.02
Phosphorus pentoxide (P_2O_5)	6.87	15.35
Sulfate ion (SO_4)	2.79	2.84
Loss on ignition	2.59	2.24

At the Tahoe plant, sludge incineration costs amount to one-sixth of the total plant operating and amortization costs, or about $1.74 per capita per year. Fuel costs and labor and material costs have gone up sharply since these data were developed, but as mentioned earlier the new Closed Loop Energy Systems furnaces eliminate the need for auxiliary operating fuel. For cities of one million population, Closed Energy Loop Systems cost about 38¢ per capita per year. Recent studies for the Boston Metropolitan Commission show for that area that combustion reclamation is the lowest cost and lowest energy use alternative, including land disposal.



Sources: WATER AND WASTE ENGINEERING MAGAZINE, WALL STREET JOURNAL, ENVIROTECH CORP.

FIGURE 4. FERTILIZER VALUE OF SEWAGE TREATMENT PLANT RESIDUAL SOLID MATTER

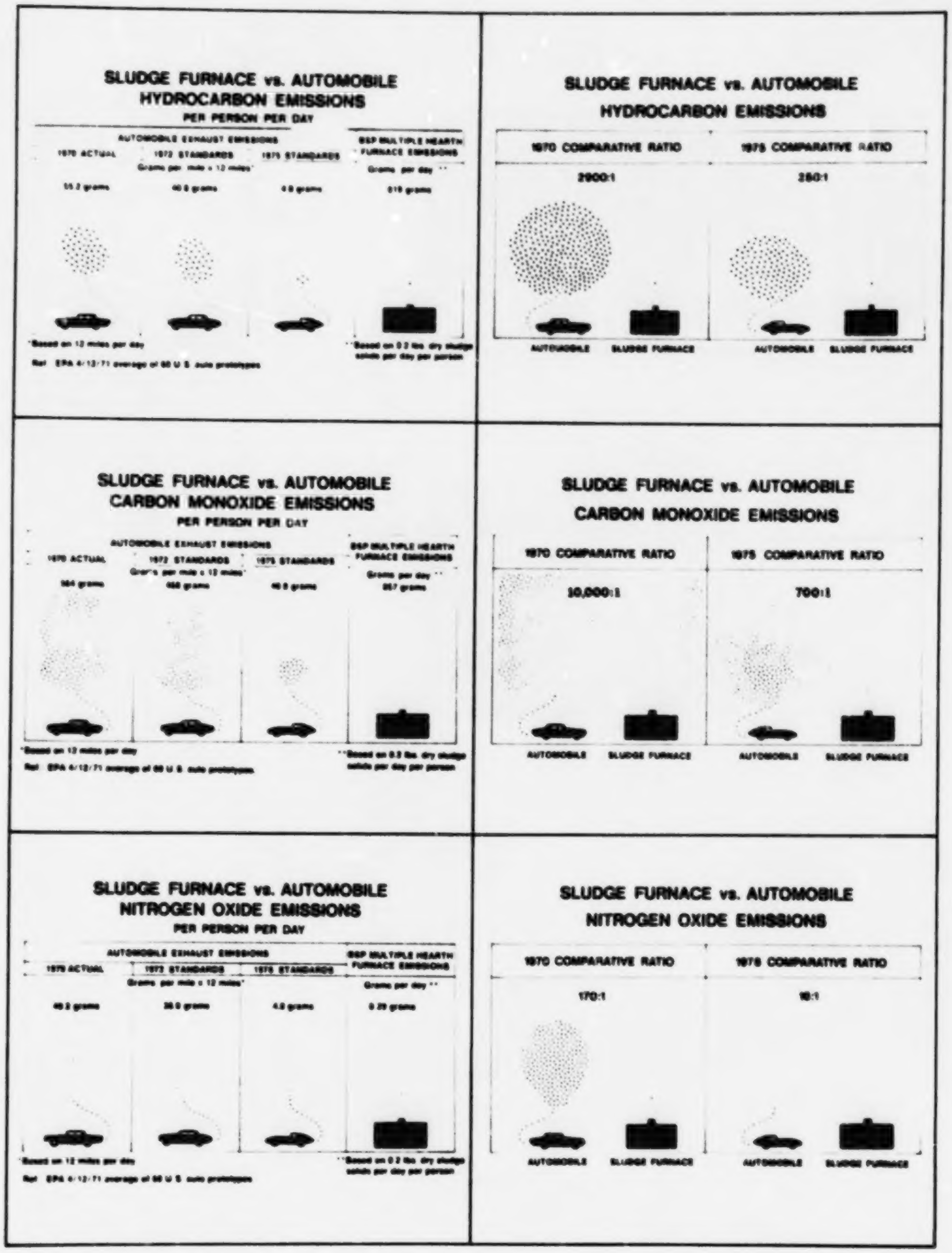


FIGURE 5. EMISSIONS OF SLUDGE FURNACE SYSTEM VS. AUTOMOBILE

For some years, systems have been operating in Europe that also use shredded waste paper as an auxiliary support source of fuel. However, when the price of waste paper went up recently, the source dried up and created problems. Obviously, availability is a potential limit to refuse scrap paper systems. A more reliable source of fuel would seem to be that of the sludge itself since one is literally converting a "sow's ear into a silk purse" on site, i.e., using the integral fuel value in the sludge to purify itself.

In the industrial sector, I should like to draw on a pulp and paper industry example to illustrate the advanced technology available. In the already mentioned GAO report to the Congress last year, it was estimated that only 5 percent to 20 percent of the technology needed for zero discharge was available as of June 1973. As an indication of either technology overlooked or progress made since that time, I should like to use an example from the bleached pulp industry to show what can be done on zero discharge. Our firm, through its joint venture with a Canadian firm, has successfully conducted pilot demonstration of a process for bleached kraft mills which produces no contaminated liquid effluent from the plant. It has just been announced that we are supplying Great Lakes Paper Company with the Erco-Envirotech Salt Recovery Process for a new 700-ton-per-day bleached kraft mill at Thunder Bay, Ontario.

In summary, briefly, some areas in which proven technology does exist and is frequently overlooked are in the water pollution control field. Water reuse technology has proved its availability to the point where treated water will meet laboratory tests for drinking water, but we need the additional R&D on long-range health effects and monitoring systems to be sure that the water continues to meet standards. Progress is being made toward zero pollution discharge requirements in the paper industry.

There are also new developments in sludge processing technology where sludge can be processed with insignificant effects on air quality and phosphate can be reclaimed as an integral part of the process.

There is a need for far more R&D on damage caused by pollution, damage eliminated by cleanup, pollutant related health effects, and the utilization of sludge ash residues for their fertilizer value, for both wet sludge and ash.

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CONCLUSIONS

Kendall D. Moll

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CONCLUSIONS

Kendall D. Moll

The systems viewpoint that permeates this proceedings is not quite what one might expect in a discussion of environmental and resource issues. It is a social rather than a physical viewpoint, reflecting the increased realization that EPA's responsibilities are basically social even though they deal with physical systems. Accordingly, EPA research programs must be set in a social systems context.

Lynton Caldwell points out in his paper that one cannot make a reasonable listing of research priorities without a structure within which to fit the various priorities. Such a structure is shown in the following illustration. Its components are the same as the six themes mentioned in the Summary. These components describe a hierarchy of research program areas organized partly by function, partly by the time horizon of the research that is needed in that component, and partly by the degree of specialization required. All of the components are related to each other either directly or indirectly within the common structure.

The top box, Environmental Systemic Interactions, represents the ties required among systems that impact on the environment. The defined systems then provide the structure for describing lower level research programs and for using research results from the lower components. Because of the large degree of abstraction of research dealing with interactions and its remoteness from direct applications, this component may be considered of long-term research interest with payoffs that may take 10 years or more.

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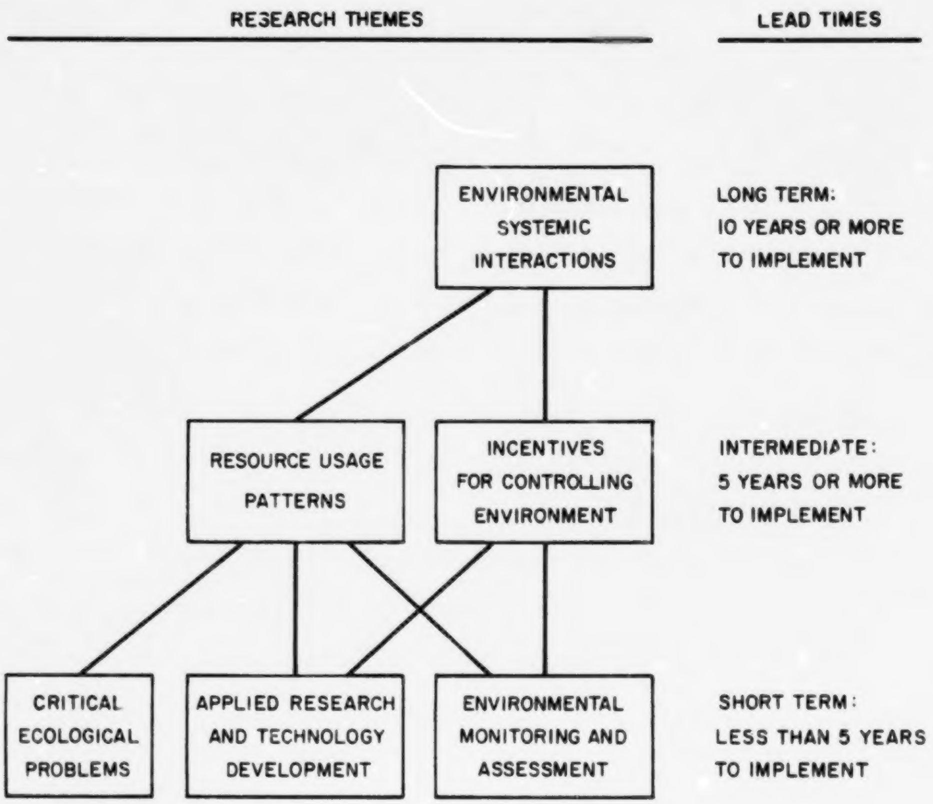
RESEARCH THEMES
LEAD TIMES
ENVIRONMENTAL SYSTEMIC INTERACTIONS
LONG TERM: 10 YEARS OR MORE TO IMPLEMENT
RESOURCE USAGE PATTERNS
INCENTIVES FOR CONTROLLING ENVIRONMENT
INTERMEDIATE: 5 YEARS OR MORE TO IMPLEMENT
CRITICAL ECOLOGICAL PROBLEMS
APPLIED RESEARCH AND TECHNOLOGY DEVELOPMENT
ENVIRONMENTAL MONITORING AND ASSESSMENT
SHORT TERM: LESS THAN 5 YEARS TO IMPLEMENT

FIGURE 1. HIERARCHY OF RESEARCH PRIORITIES

At the next lower level of the hierarchy, reflecting more concrete applications and a somewhat shorter period of response, is the component for Resource Usage Patterns. Resource usage patterns describe activities systems of a physically observable nature--such as the production and consumption patterns of asbestos. These patterns are necessary to gain an appreciation of the material, operational, and geographic nature of the processes involved.

Also at the intermediate level of response time is the third component, Incentives for Control of Environment. This subset of research tasks is designed to provide answers to motivational problems involving social and economic responses to environmental regulations.

One of the short-term response categories, Critical Ecological Problems, has become more prominent as a formal research objective in recent years because of accumulating evidence that resource usages can cause unexpected and even irreversible impacts on the environment.

Another specific area is that of Applied Research and Technology Development, in which many of the standard types of research carried on in the past can be developed more efficiently.

Finally, Environmental Monitoring and Assessment operations requires increased research and scientific inputs, to provide more complete and better integrated feedback for control of undesirable environmental impacts.

Environmental Systems Interactions

Both in terms of priority and frequency of mention in the various papers, the overriding research requirement is to develop better knowledge of the systemic interactions involved in environmental impacts, research usage, and the public interest. Several existing difficulties must be overcome. Caldwell noted that government research programs favor the immediate, low-risk, and fragmentary over comprehensive and long-term studies. Stanley Cain pointed out that the sciences (except for ecology) are not coordinated; he suggested a version of the classic land-labor-capital economic model to yield integrated insights. Robert North described several promising but still inadequate interdisciplinary approaches.

A general consensus emerged in audience discussions supporting the thesis of a new agenda for environmental research, including a systematic approach and a conceptual basis extending beyond the boundaries imposed by existing institutional arrangements. Attendees agreed that EPA should avoid the shopping list approach to R&D and instead develop a hierarchical structure based on long-term investigations such as alternative futures studies, even though the findings might go beyond typical mission-oriented agency boundaries.

Other comments dealt with the need for feedback of results: "We should pursue the grand design but at the same time we need to look at the feedback from what has been done." One iconoclast suggested "We should declare a moratorium on research until we can look back on what has been done and decide where we should go."

Other audience participants mentioned limitations that must be accepted in systems research: "There are behavioral limits to human cooperation and human skills." "Costs of not doing certain things are not accounted for."

Needs for improving implementation of objectives seem equally apparent. William Ruckelshaus pointed out that, although the founders of EPA had intentionally built the organization to tie together the different aspects of environmental control, they did not and still do not adequately deal with the interrelationships of environment and society. Industry in particular finds extreme difficulty operating under the existing fragmentation of environmental control laws and agencies. One industrial attendee stated that "environmental laws are impossible because there seems to be no process or understanding between institutions." His example illustrated that meeting a standard set by a regional control board did not necessarily mean that the state agency would approve. Another discussant pointed out conflicting agency regulations for the water use that have been set by the California Water Quality Control Board on the one hand and the Coastal Commission on the other hand.

Other perspectives on the same problem put the responsibility back on industry. "Industry must take the lead toward establishing a holistic approach to environmental protection." "An understanding of the process is necessary," and "a piecemeal approach will only result in nit-picking by control agencies."

According to another discussant, the benefits of a process approach would foster the public feedback that policymaking needs. But others added that public perception of the holistic approach requires appreciation of the risks taken by institutions moving in this direction. Similarly, legislative decision-makers who have not been educated to take a systems view of problems "need to adopt a new orientation." Typical of such barriers are the views of a prominent governor who does not like the word systematic because "he wants to see a product not a process."

A final discussant from government thought that the situation was either "serious but not hopeless or hopeless but not serious." Preferring the latter view, he remarked that "we should be relieved by the fact that a holistic approach is constrained by the political arena" and that the big picture is actually easier for an institution with fewer constraints. He suggested the university environment because of their broad investigative charters.

Flexibility is a characteristic of our present environmental control structure that must be improved. Cain noted that our social structure is not geared to technical change, but Maurice Eastin speculated that Congress will soon develop more flexible environmental control systems. Ralph d'Arge went even further in foreseeing a fundamental reorganization of control systems to deal with the emergent new class of environmental issues that are both uncertain and long term in nature.

Adaptations to the multivariate and interactive consequences of resource impacts will involve more complex information and understanding. Among the kinds of secondary and remote effects that must be addressed are those of intergenerational tradeoffs (mentioned by d'Arge), anticipated reductions in the intensiveness of agricultural production (mentioned by Zierold), organization of research efforts within or including EPA (debated by Woodwell and Galler), and constraints imposed by state and local institutions (mentioned in one of the workshops). The overall need arises from increasing evidence, as McHale pointed out, that information may be our only really unique resource, that it is inexhaustible, and that it can be applied to break the historic correlation between development and degradation.

Resource Usage Patterns

At the second level of the conceptual hierarchy, better knowledge of resource usage forms a major need. Participants noted a lack of precise and well-documented models of resource flows in the economy and environment, and Earl Heady described how agricultural models, in particular, need improvement to predict joint production functions, tradeoffs, and multiple outcomes.

Past operational experience seems sufficient to recommend certain resource policy changes even without improved research models. Ruckelshaus, in recommending more realistic policies, reflected that tough laws and spending have proved to be inadequate criteria for serving the public interest. Eastin predicted that EPA programs will shift from a negative emphasis on waste products to a more positive concern with by-products, and that to do this the programs will be reorganized around 17 resource processes instead of the present 15 functions. Another observer felt that too little use is being made of practical know-how developed by private firms operating in specialized areas and processes.

Policy conflicts should be resolved by considering the prospective marginal tradeoffs, but these are not always evident. For example, George Woodwell and Sidney Galler disagree over whether oil drilling will significantly harm fisheries on the Georges Bank. Galler agreed with John Zierold that emphasis should be given to preserving agricultural land even at large economic cost, but a member of the audience protested that no one knows if land is actually better used in agriculture than in urban development. Even knowledge of the dominant trends is not always adequate to indicate specific policy; Frank Sebastian documents how the People's Republic of China seeks food sufficiency not only by perfecting labor intensive agricultural production, but by opting when necessary for capital intensive fertilizer imports. Yet fertilizer requires large amounts of energy and other resources, and it may be deleterious to long-term soil quality and even to the ionosphere.

Because of the complexities involved in analysis of resource usage, both Caldwell and Cain recommended more impact research. Several discussants suggested cost-benefit studies of an advanced nature (but other discussants discounted the value of conventional cost-benefit and statistical work). North recommended analysis of the distribution question as well, so that social alternatives can be defined in advance of expected technical breakthroughs.

Many specific ideas for research were suggested:

(1) Analysis of resource substitutability.

(2) Options for energy transitions away from the use of fossil fuels, such as burning of forest wood.

(3) Environmental experiments.

(4) Analyses of ecosystems management objectives .

Incentives for Controlling the Environment

The second intermediate level component in the figure deals with the problem of incentives. North speculated that energy and resource problems are multiplying to the point where they threaten national and world stability, and that a breakthrough in the form of fusion, solar energy, or some comparable technology will challenge the values, institutions and lifestyles of the present society. But Zierold noted that, in the absence of breakthroughs in energy and food, exporting countries will gain more power in the world of the future than the victors of World War II had in the past. It is obviously important to attempt to maintain the social stability and incentive structure whether such changes occur or not. But discussants agreed that there is now no really unified or coherent national environmental policy aimed at future stability.

A strategy is needed not only to derive incentives for the present, but also for the future. The incentives must be designed to adapt successfully to dynamic instabilities in the resource-environment confrontation. McHale mentioned satiation as one stabilizing influence. He illustrated its effect with fat ladies, who in ancient times were status symbols as conspicuous consumers of food, but have lost their status in the current age of food abundance. Satiation will tend to limit increasing consumption of many of our resources. However, satiation will not have a chance to occur when the balance between resources and demands changes too rapidly.

Economic "externalities," in which some of the benefits or costs of an activity are not imposed directly upon the user but rather on some external group, may be destabilizing influences. This problem, mentioned by Cooper and others, must be minimized if an incentive system is to be ultimately successful. For example, recycling activities are presently inhibited by the lack of a depletion tax allowance on recycled materials and the favoritism shown for raw materials in railroad tariffs.

Ruckelshaus advocated the concept that a control system must be responsive to new conditions as well as to its original conditions. In the case of EPA, he observed that the legal adversary relationship that is developed around most issues has created a hard "win-lose" atmosphere in which accommodation and adjustment are difficult. Eastin also noted that adjustment of the existing EPA arms-length relationship with industry and the citizenry prevents mutually cooperative efforts in resolving problems. Rigidity arises in the context of environmental regulations. Red tape, conflicting laws, agency conflict, and public apathy were all mentioned by members of the audience as reasons why large-scale progress is difficult. One observer noted that only when special legislative action is taken (as for instance in the case of the Alaskan Pipeline) can major, long-term projects be accomplished.

Lack of planning and coordination has especially deleterious effects on a company designing and building a plant, for example, where long lead times are required. Many of the strongest incentives programs mentioned by the speakers--taxes, subsidies, stockpiling programs, rationing, international cooperation (all mentioned by Gordon), and open-space reserves (mentioned by Zierold)--would be either excessively expensive or completely infeasible if operated under erratic and rapidly changing policy guidelines. Some progress in alleviating this uncertainty was reported by Frank Sebastian by the setting of recommended 1977 and 1983 water quality effluent control standards.

On the international scene, it is important to ensure that all countries accept joint environmental and resource goals. Robert North suggested that research on international political systems and on comparative national trends can help in these problems, and that economic trade and technology transfer studies may provide the basis for exchanges that encompass environmental values as well as national interests.

Income distribution aspects may become increasingly significant in domestic programs. Problems of public response, which were addressed in several of the workshops, were largely oriented around how to derive and apply social indicators. In general, incentives research requires such techniques as computer simulation, forecasting, communications and education skills, economic studies such as the analysis of revealed behavior and its relationship to professed values, and (as mentioned by Cain), even insights obtained from the humanities.

In designing controls for EPA implementation, the first step is to investigate where the greatest leverage might be obtained. Also, one must examine whether this leverage is available at a reasonable cost in terms of both social acceptance and technical feasibility.

Cooper saw two types of control alternatives: one to more effectively monitor contaminant discharges and actively enforce compliance through economic incentives, emission standards, or damage liabilities; and the other to design an "idiot proof" system utilizing ecologically sound criteria that can provide redundant safeguards. The first of these alternatives would require considerable development in the areas of monitoring and control, whereas the second would require research in the area of ecological stability and hardiness. d'Arge mentioned the possibility of testing regulatory programs on a limited basis so that experience can be gained without risking large-scale ecological catastrophes. Also, experience in control activities at state and local levels can influence policies in wider areas; e.g., Wyoming has adopted some of Montana's environmental regulations.

Whatever the techniques involved, several observers note the necessity of developing better methods of information dissemination and communication to the general public on such issues as recycling. One expressed it that "the format of information receives too little attention--particularly for discrimination among different scientific disciplines by public agencies and the general public."

Beyond the EPA structure, research must be extended to consider incentives of agencies and institutions outside the EPA structure so that alternative and overlapping approaches may be considered. One member of the audience stated that he had flown over an industrial complex at 3 p.m. on a workday and noticed no dirty stack effluents, but at 5:30 p.m. he observed many smoke emissions. He presumed this change occurs because the local air quality control authorities leave work at 4:45 p.m.

Critical Ecological Problems

At the lowest level of the hierarchy of research priorities in the figure, programs with the most immediate expected payoff are gathered together. One is Critical Ecological Problems--defining research to discover environmental problems that hold the greatest hazard of severe or irreversible damage to the environment.

It is necessary if not sufficient to review discoveries and theories of academics and interested environmentalists within the system. Potential hazards, remote as they may seem upon a first hypothesis, may thereby be evaluated as quickly as possible. But the history of science is ample illustration of the difficulty of establishing review processes within the structure of an organized establishment. Ruckelshaus proposed that we build in ways for the EPA organization to systematically anticipate emergent future problems. Workshop participants suggested special studies to seek out and investigate potentially urgent environmental problems.

Other discussants identified a particular problem in the field of synthetic plastics. R&D and manufacturing capacities increasingly are used to develop synthetics as substitute materials for essential and critical materials in short supply. Since some of the new materials may be quite hazardous environmentally, EPA should sponsor "early warning" research to devise appropriate control mechanisms before these new synthetics get into full production. The group recognized that this is difficult because of industry's propensity for secrecy, especially with chemicals.

In some ways the long-term hazards are more insidious and difficult than the short-term hazards. Long-term hazards are harder to identify and eliminate unless a specific effort is made to identify these trends. Short-term hazards, on the other hand, are generally much more evident because of the obvious shifts in environmental balances that they create. d'Arge suggested that EPA focus on long-term uncertainties as a major problem area. He added that the most difficult aspect of these uncertainties are those in which interactive effects are operating. Woodwell described a specific example of uncertainty in the observed long-term buildup of carbon in the atmosphere, and its unknown future impact.

In the worst situation, uncertain hazards may result in irreversible changes. Cooper notes that extinction is such an irreversible change. Therefore, he agrees with d'Arge that irreversibility is the ultimate environmental hazard.

Applied Research and Technology Development

The central base for EPA's research program must remain its existing applied research and technology development. Among these kinds of activities, the most notable emphasis was on recycling. Zierold stated that reusability as opposed to discard will be a mandatory trend in future society. Among specific suggestions for reuse, Woodwell urged that "closed systems" be developed for local recirculation and recycling of water and sewage. Such developments would not only reduce pollution, but would also reduce the size and complexity of sewage releasing systems at great savings in resources, energy, and environment.

Sebastian documented existing progress in cleaning up areas: the British in London, Americans in Lake Tahoe, California, and South Africans in Windhoek, Namibia, have all been able to demonstrate that advanced environmental cleanup efforts provide positive savings on a cost-benefit basis alone. But additional recycling research is needed in the health and public acceptance aspects of recycled municipal water supplies, and possibly on health problems associated with the use of sludge and incinerator ash residue for commercial fertilizer. Primarily, additional information is needed on environmentally safe limits for the heavy metals in these residues.

Design and employment of resources to extend life cycles represents an alternative to the recycling approach. Zierold suggested that labor intensive activities, which necessarily involve more careful husbanding of resources, will replace current high consumptive, intensive uses.

A third approach is to find more efficiently the kinds of resources that already exist. Most of the emphasis in current U.S. energy policy reflects this approach. Gordon suggested better development and application of a number of extraction technologies; he mentions geological survey techniques such as aerial, geochemical, geophysical, seismographic, and electrical methods, and analytical techniques such as the use of mathematics and statistics in reducing geological data. He also mentioned the need for improved mining methods such as novel rock cutting and increased mine automation, economical methods of treating low-grade ores, and ocean mining and sea water recovery technologies.

As a fourth approach, Gordon and McHale both mention mineral substitution. Substitution can involve either the search for new applications of old materials, or the development of new synthetic materials.

Several attendees mentioned the need for more effective utilization of existing research results by EPA. One mentioned need for a more adequate knowledge of the state of the art in various environmental specialties. To a considerable extent, such knowledge may be available among a small group of experts, so the need might be for more effective communications with the technical community and the general public.

Environmental Monitoring and Assessment

Workshop participants agreed that continuing demands by our society to maintain current standards of living in the face of resource shortages will impose increasing pressures upon EPA. As certain of our limited resources become less available (e.g., minerals, conventional energy sources) new products will be developed and used not only as substitutes for existing products, but also in new niches for which they are especially suited. These new and substitute products with potential new problems could force EPA to expend increasing efforts in monitoring the environment. Yet, as Cooper pointed out, effective control even of existing substances will require considerable development of present monitoring methods.

Long-term environmental effects deserve particular emphasis in the monitoring problem. For planning purposes, McHale recommended that assessments be projected to periods as long as 30 to 50 years into the future.

Another frequently mentioned aspect of the monitoring problem is the need for developing quantitative relationships between the original source of disturbance and the resultant environmental change. For example, Woodwell stated his belief that the total amount of photosynthesis in the world is declining but points out that no detailed quantitative analysis yet exists to either confirm or disprove his thesis. Gordon agreed that EPA needs better economic and planning tools to assess such long-term impacts, and McHale provided another example in the need to assess agriculture pollution along with industrial pollution.

Finally, members of the audience in several of the workshops elaborated on the dominant conference theme that social assessments as well as physical environmental assessments are needed so that EPA may maintain its policies in harmony with society. Social assessment needs point to a frequently cited requirement for development of better social indicators, so that environmental and resource programs can be designed to be responsive to a fuller, more far-sighted "quality of life."

APPENDIX

SYMPOSIUM PARTICIPANTS AND ATTENDEES

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Appendix

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